EVALUATION OF CASTOR (*Ricinus communis* L.) ACCESSIONS AS FEED FOR ERI-SILKWORM (*Samia cynthia ricini* Boisduval) LARVAL PERFORMANCE AND COCOON PRODUCTION AT JIMMA, SOUTH WEST ETHIOPIA

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Evaluation of Castor (*Ricinus communis* L.) Accessions as feed for Eri-Silkworm (*Samia cynthia ricini* Boisduval) larval performance and Cocoon Production at Jimma, South West Ethiopia

By

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DEDICATION

I dedicate this thesis manuscript to my mother for nursing me with affections and love and her dedicated partnership for the success of my life.

STATEMENT OF AUTHOR

I, the undersigned, declare that this thesis is my work and is not submitted to any institution elsewhere for the award of any academic degree, diploma or certificate and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for MSc degree at the Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under the rules of the library.

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BIOGRAPHICAL SKETCH

Biftu Umer Mohammed was born on February 9, 1991 at Jimma town, Oromiya region. She attended her Primary, Secondary and Preparatory Schools at Hibret, Jiren Secondary School and Jimma Preparatory School, respectively. After successful passing of the Ethiopian Entrance Exam, she joined Bahir Dar University, College of Agriculture and Environmental Science in 2001 E.C and graduated with BSc Degree in Plant Science in 2003 E.C.

After her graduation, she was employed by Ministry of Agriculture and Rural Development office, department of cereal crop protection section and served for 9 months as cereal crop protectionist in Gambella, Itang Woreda. Then again she joined Gambella Agricultural Technical Vocational Educational Training (ATVET) College now Gambella University in 2005 E.C and worked as Instructor until she joined School of Graduate Studies of Jimma University in 2007 E.C to pursue her studies leading to Master of Science in Agronomy.

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ACRONYMS AND ABBREVATIONS

Acc	Accession
ANOVA	Analysis of Variance
CO_2	Carbon Dioxide
CRD	Completely Randomized Design
CV	Coefficient of Variation
CW	Cocoon Weight
DAP	Days After Planting
DI	Disease Incidence
DoE	Days of Emergence
DOSR	Directorate of Oil Seeds Research
DS	Disease Severity
DW	Dry Weight
ERR	Effective Rate of Rearing
FLY	Fresh Leaf Yield
FUC	Fecundity
FW	Fresh Weight
Gm	Gram
HAT	Hatchability
INL	Inter-node Length

JARC	Jimma Agricultural Research Center
LA	Leaf Area
LB	Length of Branch
LD	Larval Duration
LSD	List Significant Difference
MARC	Melkassa Agricultural Research Center
Masl	Meter Above Sea Level
MC	Moisture Content
MLW	Matured Larval Weight
NB	Number of Branches
PH	Plant Height
RCBD	Randomized Complete Block Design
SR	Shell Ratio
SRv	Survival Rate
SW	Shell Weight
VSP	Vegetative Storage Proteins

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ABSTRACT

In the development of sericulture, the quality of feed plays a remarkable role for growth and development of silkworms and ultimately on the economic traits of cocoons. The present study was undertaken to evaluate thirty two castor accessions for their leaf yielding performance and suitability as feed for eri-silkworm rearing at Eladale Research Station of Jimma University College of Agriculture and Veterinary Medicine, South West Ethiopia. Thirty two castor accessions were evaluated in randomized complete block design. Suitability of the castor accession as feed for eri-silkworms was evaluated in CRD under laboratory condition. Bothe experiments were replicated twice. Castor accessions showed significant variation both at field and laboratory experiment including biochemical composition of the leaves. Among castor accessions tested, Acc219668 registered 13890.9 kg/ha of fresh leaf yield. Higher disease severity (48.21%) was recorded on Acc219662/1. In terms of biochemical composition, higher nitrogen (3.90%) and protein (24.42%) was recorded from Acc219662/1 while high phosphorus (1.99%), fat (1.26%) and moisture (83.14%) content was recorded from Acc 200361and highest carbohydrate (52.15%) was recorded from Acc200355. However, high ash (22.9%) and fiber (24.01%) content were recorded from Acc 219647. Furthermore, significant and positive correlation coefficients were observed between eri-silkworm traits and nitrogen, protein, moisture, phosphorus, fat and carbohydrate content of the leaves. On the other hand, negative association was observed among ash and fiber contents of the leaves and eri-silkworm traits except for larval duration. Moreover, in silkworm rearing performance shorter larval duration 17.5 days, higher larval weight 7.6gm and higher fecundity 351.45 eggs/female was noticed from Acc 200361 while higher hatchability (96.75%) recorded from Acc201067. In addition Eri-worms fed on leaves of Acc 200361 were found to be superior in terms of cocoon weight (3.55 gm), shell weight (0.51 gm), shell ratio(14.33%) and ERR (98.6%). Therefore, Acc 200361 which was comparatively the best in its agronomic performance and superior for all eri-silkworms traits was recommended for future research and development work. Future studies should conduct on these accessions to see their seed yielding performance and oil quality in relation to silkworm rearing. In addition, studies should be continue giving more emphasis to multi-location evaluation of this castor accession to understand how these accessions react to diverse growing areas.

Keywords: Castor, Bio-chemical composition, *Samia cynthia ricini*, Silkworm, Cocoon traits

1. INTRODUCTION

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).

About 80% of Ethiopian population resides in rural areas. Agricultural exports are the country's source of foreign exchange. The Ethiopian government's development policy emphasizes agricultural sector development led industrialization. In 1996, the government initiated a food security strategy built around, increasing the availability of food through domestic production, ensuring access to food for food deficit households, and strengthening institutional emergency response capabilities (Berhanu, 2004). To meet this policy sericulture being an important agro based industry provides employment at various levels i.e. host plant cultivation, silkworm rearing, reeling, spinning and weaving have much impact on the improvement of rural economy (Kavane, 2014).

Silk production or sericulture is a growing industry in Ethiopia, and as the government looks to expand the textile industry in the country, it is poised to grow even more. Already in the town of Wolliso, located in the southwest Shewa zone, is a large scale silk production (sericulture) factory. It is becoming more common for farmers to raise silk worms and sell the cocoon to a factory, like the one in Wolliso, or to one of many companies in Addis Ababa as a raw product. However, the practices have never been fully exploited to directly benefit of people (Drew, 2011).

Castor plant (*Ricinus communis* L.) is a species of flowering plant in the spurge family; *Euphorbiaceae*, which contains a vast number of plants mostly native to the tropics. It belongs to a monotypic genus *Ricinus*. The name *Ricinus* is a latin word for tick. The plant is named probably because its seed has markings and a dump at the end that resemble certain tick. The common name castor oil comes from its uses as a replacement for a perfume base made from dried perinea glands of beaver (Armstrong, 1982; Weiss, 2000).

R.*communis* is cultivated all over the world and India, China, Brazil, Ethiopia, Paraguay, Vietnam and Thailand are its major grower by contributing about 97 percent of the world castor production (Anon., 2000). Castor can be grown in both irrigated and rain fed ecologies, varied climatic conditions and on almost all soils provided they are well drained and not much alkaline (Nasir *et al.,* 2013). It is an economically important plant for production of industrial oil as well as used as primary food plant for rearing of eri-silkworm, *Samia ricini* (Sarmah *et al.,* 2011).

Sericulture is both an art and science of raising silkworms for silk production. It is a farm-based, labor intensive and commercially attractive economic activity falling under the cottage and small-scale sector. It provides income and employment to the rural poor especially farmers with small land-holdings and the marginalized and weaker sections of the society (Nisar *et al.,* 2012).

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).

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 fiber (Shao and Vollrath, 2002). Silkworm is a kind of insect which can produce silk solution. The silk fiber are mostly spun by the family Bombycidae (domesticated silk; *Bombyxy mori*) and Saturniidae (mostly wild silk; *Antheraea pernyi, philosomia ricini, Samia cynthia ricini* etc.) of the order Lipidoptera (Dash *et al.,* 2007). Among saturniidae family *S.c ricini* is the one commercially exploited silkworm species and can be reared in doors throughout the year to produce silk (Joshi, 1992; Debaraj *et al*., 2003).

R. *communis* is the primary feed plant for eri-silkworm (*S.c ricini*). Being polyphagous, eri-silkworm feeds on several varieties of feed plants, which are mainly of Euphorbiaeace family. Among these the most important ones are castor (*Ricinus communis*), Dokima/bedessa

(*Heteropanax fragrans*), korch (*Evodia flaxinifolia*) and cassava (*Manihot utilissima)* (Kumar and Gangwar, 2010). Eri-silkworms reared on castor leaves yield large cocoons rich in silk content (Gezahegn *et al*., 2005; Kumar and Ganguar, 2010; Manjunatha *et al*., 2010).

Castor is the principal host plant of eri-silkworm (*S.c ricini*) (Chowdhury, 1982; Sannappa *et al*., 2004; Kumar and Elangovan, 2010). In the development of sericulture the quality of feed plays a remarkable role for growth and development of the silkworm and ultimately on the economic traits of cocoons (Hazarika *et al.,* 2005). The rearers of eri-silkworm largely depends upon the use of castor leaves in conducting rearing as it produces the best result in respect of qualitative and quantitative characters of the eri-silk (Mitalee, 2012).

According to Bhat *et al*. (1991); Raghavaiah (2003); Lakshmamma *et al*. (2009) utilization of about 30 to 40% of leaves from Castor plantations for eri-culture without negatively affecting the seed production fetch the farmer's substantial additional income apart from the regular earnings to the poor dry land cultivators besides providing gainful employment to the women. Also Devaiah *et al*., (1985) stated that Castor cultivation for eri-silkworm rearing and seed may work out the businesses to be more economical.

The quality of leaves provided to the worms for feeding has been considered as the prime factor influencing the production of good cocoon crop (Ravikumar, 1988; Bongale *et al*., 1997; Solanki and Joshi, 2001). It has been observed that growth, development and cocoon yield are influenced by the castor accession and quality of leaves fed to the worms (Chandrashekhar and Govindan, 2010; Solanki and Joshi, 2001). Therefore, it is important to get high yielding and good quality castor accession for rearing silkworm. This study was therefore planned to evaluate the quantitative and qualitative yielding ability of castor accessions for eri-silkworm production with the following objectives:

General objective

- To evaluate different castor accessions for their agronomic performance and leaf biochemical composition and their suitability as a feed for eri-silkworm cocoon production under Jimma agro-ecological conditions.

Specific objectives

1. To evaluate the agronomic performance, disease reaction and leaf yielding capacity of castor accessions under Jimma agro-ecological conditions.
2. To evaluate the suitability of castor accessions as a feed for eri-silk worm larvae.
3. To examine the relationship of the mineral and nutrient composition of castor accessions with eri-silkworm larval and cocoon traits.

2. LITERATURE REVIEW

Eri-silkworm, *S.c ricini*, is one of the most exploited, multi-voltine, domesticated and commercialized non mulberry silkworm, producing spun silk. It has many generations per year and feeds on several host plant species (Bindroo *et al.*, 2006; Chakravorty and Neog, 2006; Singh and Das, 2006)

S.c ricini can be reared completely in an indoor environment and has a great potential to grow into a big industry with proper planning and strategies (Renuka and Shamitha, 2014).

2.1. Taxonomic Classification of Eri-silkworm

Eri-silkworm, *S.c ricini*. belongs to family Saturnidae, order Lepidoptera and class Insecta (Debaraj *et al*., 2003). The classification of Eri-silk worm is as indicated in the classification tree below.

Kingdom: Animalia (Animals)
Phylum: Arthropoda (Arthropods)
Subphylum: Hexapoda (Hexapods)
Class: Insecta (Insects)
Order: Lepidoptera (Butterflies and Moths)
Superfamily: Bombycoidea
Family: Saturniidae (Giant Silkworm and Royal Moths)
Subfamily: Saturniinae (Silkmoths)
Tribe: Attacini
Genus: *Samia*
Species: *cynthia*

Source: Bill, 2012 http://www.bugguide.net/node/view/328124

2. 2. Life Cycle of Eri-Silkworms

Eri-silkworm undergoes complete metamorphosis like other Lepidopterans and has four stages: egg, larva, pupa and adult. It is a multi-voltine insect that completes 5-6 life cycles in a year (Renuka and Shamitha, 2014). The caterpillars eat most of their time, all day and night. They molt four times having five instars. They molt by gluing their feet on the ground and then just walk out of their old skin. When the caterpillars are going to pupate, they spin a white cocoon in a corner of the enclosure or between branches and leaves. Inside the cocoon the caterpillar becomes a pupa (Gezahegn *et al*., 2005). Among the four stages, larval stage is the only feeding and active stage. The duration of larval period from hatching to spinning is about 26 days on an average under ideal environmental conditions. During this long duration the larvae grow in size and enter pupal stage. To accommodate the larval body growth the larvae undergo four moults and thereby the complete larval duration which can be clearly differentiated into five instars or stadia. The first three instars (till the third moult) are known as young age or chawki and the last two instars are called as late age worms. The life cycle of eri-silkworm is depicted in fig. 1 below:

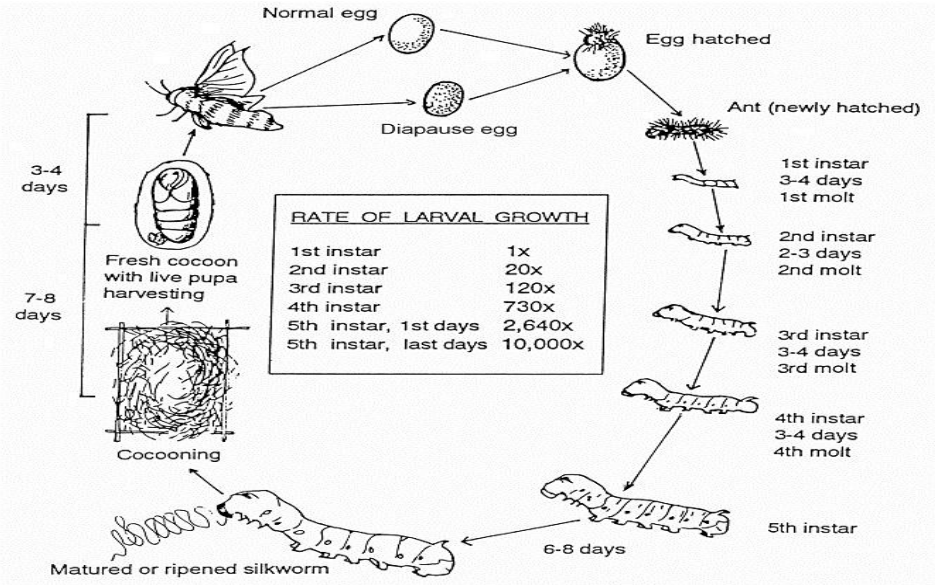

Fig. 1. Life cycle of eri-silkworm

2. 3. Environmental Requirement of Eri-silkworm

The environmental components considerably affect the genotypic expression in the form of phenotypic output of silkworm crop such as cocoon weight, shell weight, and cocoon shell ratio. The variations in the environmental conditions day to day and season to season emphasize the need of management of temperature and relative humidity for sustainable cocoon production (Rahmathulla, 2012).

2.3.1. Temperature and humidity

Temperature has a direct correlation with the growth of silkworms. Wide fluctuation of temperature is harmful to the development of silkworm. The optimum temperature for normal growth of silkworms is between 20°C and 28°C and the desirable temperature for maximum productivity ranges from 23°C to 28°C (Krishanswami *et al.*, 1973: Datta, 1992; Karuna and Devi, 2008).

Temperature above 30°C directly affects the health of the worm. If the temperature is below 20°C all the physiological activities are retarded, especially in early instars as a result, worms become too weak and susceptible to various diseases. Rise in temperature increases various physiological functions and with a fall in temperature, the physiological activities decrease. Increased temperature during silkworm rearing particularly in late instars accelerates larval growth and shortens the larval period (Hazel, 1995; Willmer *et al*., 2004). On the other hand, at low temperature, the growth is slow and larval period is prolonged. The temperature requirements during the early instars (I, II, III) are high and the worms feed actively, grow very vigorously, and lead to high growth rate (Tazima and Ohuma, 1995; Hussain *et al*., 2011; Rahmathulla, 2012).

Increase in temperature beyond 35°C causes less spinning, mortality of larvae and pupae and poor moth emergence and sterility at adult stage (Sugai, and Takashashi, 1981; Sahu *et al.*, 2006).

Humidity plays a vital role in silkworm rearing and its role is both direct and indirect. The combined effect of both temperature and humidity largely determines the satisfactory growth of the silkworms and production of good-quality cocoons. It directly influences the physiological functions of the silkworm. The young-age silkworms can withstand to high humidity conditions than later-age worms and under such condition, the growth of worm is vigorous (Rahmathulla, 2012). On the other hand humidity indirectly influences the rate of withering of the leaves (feed) in the silkworms beds. Under dry conditions the leaves wither very fast and become unsuitable for feeding. This affects growth of the larvae and also results in wastage of leaf. The optimum humidity conditions required for different developmental stage is 65-90% (Karuna and Devi, 2008; Mubashar, 2011). Lower relative humidity level less than 65% is not conducive for seed cocoon production and increase larval mortality even at the optimum temperature of 25°C (Hussen *et al.*, 2011).

Table 1: Instar based requirement of temperature and humidity for eri-silkworm

Environmental factor	I instar	II inatar	III instar	IV instar	V instar
Temperature	26-28^{0}c	27^{0}c	26^{0}c	25^{0}c	24^{0}c
Humidity	85-90%	85-90%	80-85%	70-75%	65-70%

Source: Mridul, 2010; Mubashar, 2011; Rahmathulla, 2012

2.3.2. Sunlight

Silkworms are photosensitive and they have a tendency to crawl towards dim light. Rearing of silkworms in continuous light delays the growth. Further, it causes penta-moult and reduces both larval and cocoon weights. Silkworms are fond of dim light of 15 to 20 lux and avoid strong light and darkness. Late-age worms survive better in 16-hr light and 8- hr dark periods. However, young-age worm prefers 16 hr darkness and 8 hr light period. Larvae of silkworm do not prefer either strong light or complete darkness but usually light phase, in contrast to the dark phase, activates the larvae (Rahmathulla, 2012).

2.3.3. Air

Like other animals silkworms also require fresh air. By respiration of silkworms carbon dioxide gas is released in the rearing bed. Besides this carbon monoxide, ammonia, sulphur dioxide etc., are also released in the rearing room by burning of charcoal to raise temperature during cold days. These gases are injurious to silkworms. Therefore care should be taken to allow fresh air through proper ventilation to keep the toxic gases at a low level. If CO_2 exceeds 2 per cent concentration, the growth of silkworm is retarded (Karuna and Devi, 2008).

2. 4. Management of Eri-silkworm Production

2.4.1. Feeding

The suitability (nutritive value) of feed plant leaves differs accordingly to the period of larval growth. Without physical and biochemical knowledge, the leaf quantity cannot be judged according to the position of the leaves on the plants. While plucking leaf from the same shoot, the softness and the degree of maturity may vary widely according to the position of the leaves on the standing plant in the field. Therefore, it is desirable to pluck more than one leaf from one shoot which appeared to be suitable for the worm's particularly young ages (Mridul, 2010).

Also the number of feeds in each instar plays a major role in the cocoon built. Three to four feeds are given to the silkworm. During moulting period no feeding should be given. Before settling to moult and immediately after moult, first feeding should not be heavy. Feeding tender leaves to young age worms is essential. As the larval growth advances the mature leaf can be fed. Maximum leaf is consumed during 4^{th} and 5^{th} instar only. During this stage only the maximum growth of silk gland can be noticed. It is estimated that 50% of the total weight will be increased in the 5^{th} instar itself (Ito, 1967; Ahmad *et. al*, 2006).

2.4.2. Cleaning

As soon as the larvae grow-up, the unconsumed leaves and litter increase in the rearing bed which ultimately cause changing atmosphere and favoring multiplication of pathogenic organisms. Hence, timely bed cleaning is essential to keep the worms healthy (Mridul, 2010). The frequency of cleaning is increased as the age of the larvae increases (Dandin *et al*, 2003).

2.4.3. Spacing

The maintenance of optimum number of worms per unit area according to the size or stage of the worms during rearing is called spacing of worms (Mridul, 2010). As silkworms grow and develop the size of the rearing bed should be enlarged accordingly they should be arranged evenly neither too crowded nor spaced to far apart (Dandi *et al*, 2003).

Table 2: Instar based feeding, cleaning and spacing of eri-silkworm

Stage	Feeding			Spacing for 100dfls* (Sq. ft)	Cleaning frequency	Time of Cleaning
	Amount of feed for 400dfls*(Kg)	Frequency of feeding (time/day)	Type of leaves			
1st Instar	2-4	3	Tender	4-14	1 time	Before first moult
2nd Instar	4-8	3	Tender	15-45	2 time	After first moult and before second moults
3rd Instar	30-40	4	Semi- tender	46-90	3 times	After second moult, middle of third instar and before 3rd moult
4th Instar	80-90	5	Mature	91-100	Once in a day	Every day in the morning
5th Instar	600-650	5	Mature	181-360	Twice in a day	Every day in the morning and in the evening

Source: Dandi *et al.*, 2003; Mridul, 2010

- Dfls: disease free layings

2.4.4. Mounting

Transferring of mature fifth instar larvae to mountages is called mounting. It is the last stage of rearing operation. After completion of larval life span, the matured 5^{th} instar larvae stop feeding and become restlessly moving here and there to search a suitable place for cocooning and also discarded its complete excreta consisting of liquid and semi-solid substances which indicate the time to transfer the mature larvae into the mountages (Gezahegn *et al*., 2005; Mridul, 2010; Ahmed *et al*., 2015).

2.4.5. Harvesting of cocoon

The last and important step in silkworm rearing is harvesting of cocoons from the mountage in time. Cocoons should be harvested after 5-6 days of spinning in summer and 8-9 days in winter (Mridul, 2010). Harvesting should not be done immediately after pupation. Further, harvesting should be done before the moth emerges out. Too many days delay in harvesting will result in formation of pierced cocoons due to emergence of adult moth or uzi maggots (Krishnawami *et. al.,* 1979a)

2.5. Host Plants for Eri-silkworm

Eri-silkworm feeds on leaves of many food plants including Castor *(Ricinus communis),* Dokima/bedessa (*Heteropanax fragrans*), korch (*Evodia flaxinifolia*), cassava (*Manihot utilissima*), Jatropha (*Jatropha curcas*), Papaya (*Carico papaya*) etc. All the food plants are not equally good for eri-silkworm rearing. Eri-silkworm show different behavior, when reared on different food plants. The primary host plants for eri-silkworm are Castor (*R.communis*) and Papaya (*C. papaya*). Jatropha and cassava being the secondary host plants (Kumar and Gangwar, 2010).

Among all host plant castor (*R. communis*) is the most preferred host plant for eri-silkworm (*S.c ricini*) (Sannappa *et al*., 2004; Singh and Das 2006; Sannappa *et al*., 2007; Kumar and Elangovan, 2010). The rearers of eri-silkworm largely depend upon the use of castor leaves in

conducting rearing as it produces the best result in terms of qualitative and quantitative characters of the eri-silk (Mitalee, 2012; Venu and Munirajappa, 2013).

A study on the worms fed with castor leaves were found to possess predominantly higher content of the metabolites followed by jatropha and papaya (Vittal, 2004). Also according to Bhat *et.al*.(1991); Chandrappa *et.al*.(2012) being *R. communis* is the primary food plant of eri silkworm, *S.c ricini* 30 to 40 percent of the total leaf yield can be harvested and used for eri-cocoon production without affecting castor seed yield.

Similarly, the research findings of Directorate of Oil seeds Research (DOSR), Hyderabad revealed that defoliation to an extent of 25%-30% does not affect the seed yield of castor as it has tremendous regenerating capacity (Teotia *et al*., 2003). Castor plant has established its superiority with other host plants by encouraging the growth and development of eri-silkworms (Venu and Munirajappa, 2013)

2.6. Influence of Different Castor Genotypes on Eri-silkworm Performance

S.c ricini belonging to family saturnidae, is the one among the commercially exploited silkworm species and can be reared indoors throughout the year to produce silk depending on the availability of suitable host plants (Debaraj *et al*., 2003). Eri-silkworm is known to feed on the leaves of more than 30 host plant species, castor is considered as the principle host plant (Govindan *et al.,* 2002).

Previous workers studied rearing performance of eri-silkworm using the leaves of different food plants and they have recorded varied results such as prolonged larval duration, reduced larval weight, cocoon weight, shell weight, shell ratio and pupal weight (Dutta and Khanikor, 2005; Mukul *et al*., 2011).

Even if castor is primary feed for eri-silkworm, the quality of leaves provided to the worms for feeding by different accession has been considered as the prime factor influencing the production of good cocoon crop. It has been observed that growth, development and cocoon yield are influenced by the castor genotype and quality of leaves feed to the worms. The

selection of castor genotypes is an important factor for better growth and development of eri-silkworm for higher productivity in terms of cocoon yield (Chandrashekhar and Govindan, 2010).

Dasari *et al.* (2013) observed significant variation in terms of larval duration, larval weight, Cocoon weight, Shell weight, and Shell ratio while eri-silkworms feed on five different castor genotypes. Among the five variety of castor tested (DCS-9, 48-1, DCH-519, DCH-177 and local) the performance of eri-silkworm in terms of larval traits and cocoon traits showed significant difference while feeding those different castor genotype. Local variety and DCH-519 castor genotypes are found to be superior in terms of shell ratio during three seasons. Also they concluded that the variation in silkworm performance is the result of nutrient and mineral composition of the leaf which has direct relationship with silkworm growth and development.

Chandrappa *et al.* (2012) studied the effect of different genotype on seed yield and eri-cocoon production under rain fed condition. They observed that among ten castor genotypes the hybrid castor JI-226 followed by DCS-85 genotype were promising and could be used with cost effectiveness for dual purpose of castor seed and eri-cocoon production under rain fed conditions.

Sarmah *et al*. (2011) reported significant variation in terms agronomic parameters and rearing performance of eri-silkworm from eight castor accessions viz., Ac01, Ac03, Ac04, Ac11, Ac20, Ac30, Ac36 and Ac56. According to their results Ac03 and Ac04 castor genotypes were found to be better in terms of agronomical and yield attributing traits together with silkworm rearing performance.

2.7. Importance of Leaf Quality and Biochemical Content for Eri-Silkworm Production

Leaf quality is an important parameter used for evaluation of genotypes aimed at selection of superior variety for rearing performance (Bongale *et al*., 1997). It is a confirmed fact that leaf quality differs among varieties and specific components of the leaves which are responsible

for the difference in rearing performances of the silkworm (Machii and Katagiri, 1990; Aruga, 1994).

The quality and quantity of castor leaves therefore, play an important role in growth and development of eri-silkworm, particularly during adult and larval stages, which in turn influence the cocoon productivity and the economic traits of the cocoon. Good quality and sufficient quantity castor leaves feeding to the developing worms leads to an increase in body size and dry weight of cellular mass which are dependent on the rate of metabolism, absorption of nutrients, and stage of development (Rajanna, 1991). Also Matsumara *et al.* (1958) and Joshi (1992) opined that quality of castor leaves contributes 38.20 per cent for quality cocoon production.

The quality and quantity of the leaves has a profound effect on the superiority of silk produced by S. c *ricini*. Leaves of superior quality, free from diseases and dust, enhance good cocoon production (Ravikumar, 1988). It has also been demonstrated that the dietary nutritional management has a direct influence on quality and quantity of silk production in eri-silkworm (*S.c.recini*) (Murugan *et al.,* 1998). On top of this Sarkar *et al.* (2015) reported that, food quality can reduce the actual performance of an insect below its physiological potential.

Highly nutritious and balanced nutrient food are the prime factors responsible for healthy growth and development of any insect, as it provides the ultimate source of energy to the insects. (Mitalee, 2012). Moreover, growth and development of silkworms and the cocoon crop yield are considerably influenced by the nutritive value of leaf as feed, which even varies from variety to variety of the same species (Sarmah *et al*., 2013).

Silkworm nutrition is one and the major factor which affect development and productivity of silkworms (Ogunbanwo and Okanlawon, 2009). Nutritional requirement in food consumption had direct impact on the overall 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 (Raina *et al*., 2004a; Seidavi *et al*., (2005).

2.7.1. Leaf protein content

The protein content in different sericigenous plant is highly variable. 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. Proteins are required in all the stages of silkworm especially a higher quantity of protein is essential for the formation of sericin and fibroin during spinning of the silk cocoons (Fukuda *et al*., 1960).

In silkworms silk Fibroin is derived mainly from four amino acids: alanine, serine, glycne and tyrosine which come from their dietary source of protein and amino acids (Fukuda *et al*., 1960; Ito, 1983). Silkworms obtain 72-86% of their protein from feed leaves and more than 60% of the absorbed proteins are used for silk production (Lu and Jiang, 1988).

2.7.2. Crude fiber content

Crude fiber is indigestible part of foods. Therefore, it is required in lesser amount as they interfere with digestibility of the feeds (Maynard and Loosli, 1962). It comprises largely of cellulose and lignin and these substances belong to carbohydrate, but cannot be digested by silkworm larvae. Fiber is not grouped under nutrients, but its intake along with all diet is essential because of regulatory function and help to maintain the normal peristaltic movement of the intestine to remove waste product from the intestine (Vasuki and Basavanna, 1969).

2.7.3. Carbohydrate content

Carbohydrates play an important role as energy sources during the development of embryo and other metamorphic stages (Maynard and Loosli, 1962). Carbohydrates, particularly reducing sugars are very important for growth and development of silkworms. Carbohydrates are utilized by the silkworms for energy source and for synthesis of both lipid and amino acids. However, the greater part of the carbohydrate content of leaves is used for physiological combustion (Ito, 1960; Maynard and Loosli, 1962).These are very important for healthy growth of silkworm especially they are effective for keeping healthy growth of infant larvae. Some sugars possess a gustatory stimulation effect on larval feeding of the silkworm

(Ito, 1960). In case of eri-silkworm feeding with castor leaves a nonlinear regression equation was estimated with larval and cocoon weight and ERR as dependent variable and leaf biochemical parameters as independent variables (Sarmah *et al.*, 2011). The carbohydrates are generally the most effective in increasing fat body glycogen (Horie, 1978).

2.7.4. Phosphorus content

Phosphorus is necessary for better silkworm growth and development and for increased cocoon production. Its deficiency results in retarded growth (Sidhu, *et al.*, 1969; Ray *et al.*, 1973). Shyamala and Bhat (1968) reported better phosphorus use efficiency by young-age silkworms and its assimilation in young stages was 63-65%. Phosphorus is known to improve the total sugar content of leaf (Ray *et al.*, 1973). Thus phosphorus management becomes crucial. Phosphorus deficiency in mulberry leaf increases the extent of flacherie (Anonymous, 1980).

2.7.5. Fat content

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).

Generally 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 (Fukuda *et al.*, 1960). Krishnaswami, (1978) also stated that silkworm feed with more moisture, protein, sugar and carbohydrates and less minerals and crude fiber content is the best from the silkworm nutrition point of view.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field study was conducted in the 2015/2016 rainy seasons at Eladale Research Station of Jimma University College of Agriculture and Veterinary Medicine, southwest Ethiopia (N 7°40' E 36°50', 1753 m.a.s.l.), with long-term average annual rainfall of 1500 mm, average monthly relative humidity of 91%, average daily maximum and minimum temperatures of 26.8 and 11.8°C, respectively (Abera *et al.*, 2011). The dominant soils of the area are Nitisol and Cambisol which are drained and has favorable physical property for agricultural practices and well recognized as the most productive soils in Ethiopia (Mesfin, 1998)

3.2. Experimental Materials

Thirty two selected accessions of castor (Table 3) were obtained from Melkassa Agricultural Research Center (MARC). These castor accessions were selected from hundred accessions of castor collected from various parts of the country based upon their yield performance and maintained at MARC. Further, eggs (seeds) of eri-silkworm were brought from Jimma Agricultural Research Center (JARC) for evaluation of eri-silkworm performance up on feeding of the above mentioned different castor accessions.

Table 3. List of castor accessions used as treatment for experiment

S.N	Notation	Accessions	S.N	Notation	Accessions
1	T_1	Acc 200361	17	T_{17}	Acc 212534
2	T_2	Acc 200377	18	T_{18}	Acc 212631
3	T_3	Acc200390	19	T_{19}	Acc219627
4	T_4	white castor	20	T_{20}	Acc21963
5	T_5	Acc200355	21	T_{21}	Acc219645
6	T_6	Acc203644	22	T_{22}	Acc 219647
7	T_7	Local (Jimma)	23	T_{23}	Acc219648

8	T_8	AccM-16	24	T_{24}	Acc219650
9	T_9	Acc219662/1	25	T_{25}	Acc219653
10	T_{10}	Acc Hiruy(Gk-sel-1)	26	T_{26}	Acc219654
11	T_{11}	Acc GE-sel-1/63-271	27	T_{27}	Acc219662
12	T_{12}	Acc208950/2	28	T_{28}	Acc219665
13	T_{13}	Acc106501	29	T_{29}	Acc219668
14	T_{14}	Acc106564	30	T_{30}	Acc219671
15	T_{15}	Acc201067	31	T_{31}	Acc219673
16	T_{16}	Acc203241	32	T_{32}	Acc219682

3.3. Experimental Design

In the experiment, both RCBD and CRD designs were used. To evaluate the agronomic performance of thirty two castor accessions, treatments/accessions were arranged in Randomized Complete Block Design (RCBD) with two replications while the feeding experiment in laboratory to identify the best accession as a feed for eri-silkworm was arranged in Completely Randomized Design (CRD) with two replications for each treatment (32 accessions).

3.4. Experimental Procedures

The castor accessions were sown with a spacing of 75cm x 70cm between rows and between plant, respectively and the plot sizes were kept constant at 2.8 × 3 m each. Each plot comprised four lines having 16 plants per plot. The two outer rows of plants were treated as border rows, while the two middle rows in each plot were regarded as net plot. Four sample plants from net plots were taken as sampling points for data measurements. Blocks and plots were spaced 2m and 1m apart, respectively making the total experimental area 825 m^2.

Castor accessions were planted and managed similarly in each and every plot except for the differences in their genetic make-up. Phosphorus and nitrogen were applied in the form of DAP and Urea as per the recommendation given by Gangaiah (2012). Phosphorus was

applied during planting time at the rate of 40 kg/ha and nitrogen was applied at planting and at the first weeding at the rate of 40 kg/ha. First weeding was done 30 days after sowing and the second and third weeding was done in 60 and 90 days after planting, respectively.

To observe the performance of the silkworms up on feeding 32 accessions of castor standard tray rearing method was used as recommended by Sarkar (1988). *S.c ricini* was reared using completely randomized design (CRD) with two replications for each treatment in the laboratory. The laboratory was assumed to have a temperature of 25-27 ^{0}c and relative humidity of 75-80%. In each tray there were 20 health late age (III to IV instars) worms. The silkworm rearing room and equipments was cleaned, washed and disinfected with 2% formalin solution at the rate of 800 ml/10 m^2 before the commencement of the experiment (Dayashankar, 1982). The laboratory experiment was conducted on late age silkworms this was because the critical stage for cocoon production and quality cocoon is depends on the late age feeding management of the silkworms (Dandin *et al*., 2003). Tender leaves 0.1kg/20dfls of castor were fed three times a day until the larvae ends 2nd instar and semi tender 0.15kg/20dfls leaves to 3rd instar four times a day. 4th and 5th instar worms fed with matured leaves four times a day at the rate of 4kg/20dfls and 30kg/20dfls respectively. During the experiment accessions were fed to the worms irrespective of the block consideration in the field, i.e., castor leaves from a given plot were harvested and divided in to two equal parts and provided to the developing silkworms. Cocoon harvesting was carried out after five and six days of spinning. This procedure was conducted for two life cycles of silkworm this was because we didn't know their background fed at JARC. Therefore, repeating of rearing experiment makes us to be sure about the performance of the accession as feed for silkworms without effect of their background feeding. The first rearing was conducted from (Feb -Apr) and second rearing was conducted from (May-July, 2016).

3.5. Data Collected

3.5.1. Agronomic parameters

3.5.1.1 Days to 50% emergence: - Days to emergence was determined by taking the percentage of emerged seedlings at different days after planting (DAP).

3.5.1.2. Length of primary branch: - Length of the primary branch was measured using tape meter at physiological maturity from the main stem to the tip of the branch.

3.5.1.3. Plant height: - Plant height was measured at physiological maturity from the ground level to the tip of the main stem of castor sampled plants which were selected from the central two rows of the treatments and from each replication.

3.5.1.4. Inter-node length: - Inter-node length was measured using ruler at physiological maturity.

3.5.1.5 Leaf area: - Leaf area was measured using leaf area meter from five fully matured leaves of each treatment.

3.5.1.6. Leaf moisture content (LMC):- This was measured by taking fresh and dry weight of the leaf (Mbow, 1999).

$$\text{MC\%} = \frac{FW - DW}{FW} x100$$

Where:- MC: moisture content, FW: fresh weight, DW: dry weight

3.5.1.7. Fresh leaf yield:- Fresh leaf yield was calculated on 90 DAP at start of rearing by counting number of leaves per plant and multiplying it by the corresponding fresh leaf weight. Then the weight of leaves obtained in single plant base was converted to plant population per hectare.

3.5.1.8. Disease incidence and severity:- During the experimental period rust and cercospora leaf spot disease were observed. However, Cercospora leaf spot (*Cercospora riciella*) which was a serious problem at growing season was recorded from sample plants and disease incidence and severity value were calculated by adopting disease-rating scale 1-5 (Vir and Grewel, 1974): Where: grade 1 = no infection; grade 2 = 0–5% infection; grade 3 = 6–25% infection; grade 4 = 26–50%; grade 5 = 51–100% infection.

$$\text{Disease incidence} = \frac{\text{No. of infected plants}}{\text{Total no. of plant assessed}} x100$$

$$\text{Disease severity} = \frac{\text{Sum of all disease rating}}{\text{Total no. of rating } x \text{ maximum disease grade}} x100$$

3.5.1.9. Mineral and nutrient composition:- Mineral and nutrient composition of leaves were determined by taking leaf sample leaves from all treatments which were grown at the middle row in the plot. The leaves were collected at three different heights of the plant viz. top, middle and bottom in paper bags. They were oven dried at 70^{O}C until constant weight was obtained. Then, the dried-up leaf samples were grinded in to fine powder and were subjected to laboratory analysis for the determination of mineral and nutrient composition. N and P were determined using techniques and procedures as described by Sahlemedhin and Taye (2000). Nutrient composition such as ash and total carbohydrate were determined according to methods developed by Ranjhan and Krishna (1981) while crude fiber and crude fat were determined by techniques and procedures outlined by Association of Official Analytical Chemists (A.O.A.C.) (1970). Crude protein was estimated by multiplying the estimated value of the total nitrogen by 6.25 (Sahlemedhin and Taye, 2000).

3.5.2 Larval parameters

3.5.2.1. Fecundity: - After emergency of the moth from the cocoon, male and female eri-moths were sexed and the number of eggs produced by single female was counted by using ink/sketch pen replication and treatment wise.

3.5.2.2. Hatchability (%): - Hatchability was estimated by subtracting the number of non-hatched eggs from total number of egg laid and then divided by the normal eggs (Singh and Benchamin, 2002).

$$\text{Hatchability} = \frac{\text{No. of normal egg} - \text{No. of non hatched eggs}}{No.\,of\ normal\ eggs}$$

3.5.2.3. Survival rate (SR):- SR was measured by dividing the number of survived larva by number of larva brushed multiplied by hundred (Singh and Benchamin, 2002).

$$\text{Survival rate} = \frac{\text{No. of survived larvae}}{No.\,of larvae\ brused} x100$$

3.5.2.4. Larva duration:- The total larval duration is the period between hatching of eggs and maturity of the larvae and was recorded in each treatment in days.

3.5.2.5. Matured larva weight:- The weight of matured larvae was taken when the larvae stopped eating, body become pale and excreted the last excreta. Five larvae were randomly picked from each treatment and weighed treatment and replication wise and the average was calculated.

3.5.3. Cocoon parameters

3.5.3.1. Effective rate of rearing (ERR) (%):- ERR was measured by dividing number of larvae spinning cocoon to larvae brushed and expressed in percentage (Singh and Benchamin, 2002).

$$\mathbf{ERR} = \frac{\mathbf{No.\ of\ larvae\ spinning\ cocoon}}{\text{No. of larvae brushed}} x100$$

3.5.3.2. Cocoon trait:-The following cocoon traits were determined:-

a) Single cocoon weight (gm): The weight of the cocoons produced by the larvae was recorded treatment and replication wise. The weights of randomly selected five cocoons were measured using sensitive balance and average was taken.

b) Single shell weight (gm): Randomly selected five cocoons were cut open and the average weight of the shell was recorded treatment and replication wise.

c) Shell ratio: Shell ratio is the amount of silk present in a cocoon shell and expressed in percentage as indicated below.

$$\text{SR\%} = \frac{weight\ of\ the\ cocoon\ shell}{weight\ of\ the\ cocoon\ with\ pupa} x100$$

3.6. Data Management and statistical Analysis

All the data were examined for homogeneity of variance and normality. Then, those data which were found to have normal distributions were subjected to analysis of variance using SAS statistical software package 9.2 (SAS, 2008). The differences between treatment means were compared using least significance difference (LSD) test at 5% level of significance. Pearson's correlation analysis was done to observe the relationship between leaf biochemical compositions and eri-silkworm traits.

4. RESULTS AND DISCUSSION

4.1. Field Performance of Different Castor Accessions

The agronomic performance of the thirty two castor accession were evaluated at the Jimma University, College of Agriculture and Veterinary Medicine research farm Eladale research site during the 2015/2016 academic year.

Significant variations have been observed in agronomic performance among the castor accessions and the results obtained are presented and discussed below.

4.1.1. Days to 50% emergence

Analysis of variance of the data revealed that days to 50% seedling emergence was highly significantly ($P<0.01$) affected by different accessions (Appendix 1). In this experiment, the early emerged accession was AccM-16 which took 9 days to emerge. Acc219650, Acc219653, Acc219668, Acc219673, Acc208950/2, Acc219648, Acc 200377 and Acc200355 were late emerged accessions which emerged 12 days after planting. The local check took 10.5 days for emergence and it was early emerged accession as compared to the other 30 accessions except AccM-16 (Table 4). The variation in emergence was supported by Oplinger *et al*. (1990) who reported that depending up on the variety and seed size castor seed takes 10 to 12 days to emerge. Ozturk *et al.* (2014); Williams and Swinbank (2014) reported that castor requires 10 to 21 days for seedling emergence depending up on soil moisture and castor varieties.

In the present study the soil moisture was maintained uniform for all experimental units. Therefore, the variation observed in emergence is only due to the differences in castor accessions in the experiment.

4.1.2. Number of primary branches and Branch length

There were significant variation in terms of number of primary branches and branch length among treatments. The highest number of primer branch (8.7063) was recorded from

Acc200361 and the lowest number (2.7625) was recorded from Acc208950/2. The local check had 3.5438branches/stem (Table 4). In addition, in the present experiment the longest primary branch (226.25 cm) was recorded from Acc 212534 and shortest (109.38 cm) was recorded from Acc208950/2. This result is supported by the finding of Kedir (2011) who observes significant variation in number of primary branches and branch length between different castor genotype. In addition Sannappa *et al*. (2016) observed maximum number of branch per plant (9.11) on DCH-519 castor hybrid and minimum (3.889) on local green variety.

The finding of Sarmah *et al.* (2011) who observed high number of branch (4. 83) in Acc001, Acc003 and Acc30 and lowest (3.00) in Acc004 is also in agreement with the finding of the present study. This variation among different castor accession is may be due to the difference in genetic makeup of castor accessions. Number of branches per plant is genetically controlled characteristic (Vender *et al.*, 1995).

4.1.3. Plant height and inter-node length

Significant variations were observed in plant heights and inter-node length which ware measured on plant basis. Plant heights for the test accessions ranged from 1.38 m (Acc106564) to 2.90 m (Acc219627). In addition, inter-node length varied from 15.25cm for Acc208950/2 to 28.875cm for Acc219662. On the other hand medium plant height and inter nod distance (198.13cm and 16.625cm) respectively was recorded in local castor accession (Table 4). The variation in plant height and inter-nod length obtained in this study indicates the existence of heterogeneity among castor accessions for these agronomic characteristics. Similar with this study castor genotype GKsel was reported to have longest (173.55cm) plant height while genotype Bako has shortest plant height (142.33 cm). On the other hand, Abaro genotype registered the longest inter-node distance (9.29 cm) while Bako registered shorter inter-nod distance (5.95 cm) (Kedir, 2011).

Also according to the findings of Sarmah *et al*. (2013), field trial of two promising castor genotypes for eri-silkworm rearing indicated that there was significant difference in plant height and inter-node length between the two accessions. Besides, Govindan *et al*. (2003)

observed a significant variation among castor hybrids with respect to plant height at different days of sowing. Among the genotypes they considered, DCH-177 hybrid registered higher plant height, at 45, 90, 105, 120 and 135 days after sowing, in comparison to local pink powdery variety. The variation in terms of plant height and inter-node length is may be due to the inherent variation of those castor accessions. Plant height and inter-node length is controlled by inherent genetic constitution of plant (Abdellah, 1991).

Table 4. Agronomic performance (DoE, NB, BL, PH & INL) of castor accessions, at Jimma, 2015/2016

Castor accession	DoE (days)	NB (number)	BL (cm)	PH (cm)	INL (cm)
Acc 200361	10.5^{bc}	8.7063 ^{a}	157.75^{bcdefg}	205.75^{cdefghi}	27.625^{ab}
Acc 200377	12^{a}	3.3938^{ijk}	144.13^{defg}	162.75^{ghi}	19^{cde}
Acc200390	11^{abc}	4.5063 ^{efghijk}	185.75^{abcde}	195^{efghi}	17.625^{de}
white castor	10^{cd}	5.4625 ^{cdefgh}	175.38^{abcdef}	208^{cdefghi}	21.875^{abcd}
Acc200355	12^{a}	3.6125 ^{ghijk}	150.63^{cdefg}	190.25^{efghi}	21.25^{bcde}
Acc203644	11^{abc}	4.3438^{efghijk}	131^{efg}	216.88^{bcdefgh}	15.375^{de}
Local	10.5^{bc}	3.5438^{hijk}	132.13^{efg}	198.13^{defghi}	16.625^{de}
AccM-16	9^{d}	7.0375^{abc}	147.75^{cdefg}	188.88^{efghi}	15.875^{e}
Acc219662/1	11.5^{ab}	4.7625^{efghij}	213.5^{ab}	287.5^{ab}	28.875^{a}
Acc Hiruy(Gk-sel-1)	10.5b^{c}	5.2563^{cdefghi}	191.38^{abcd}	172.88^{efghi}	19.375^{cde}
Acc GE-sel-1/63-271	11.5^{ab}	5.2563 ^{cdefghi}	181.5^{abcdef}	150.25^{hi}	21.125^{bcde}
Acc208950/2	12^{a}	2.7625^{k}	109.38^{g}	167.63^{fghi}	15.25^{e}
Acc106501	11^{abc}	5.4563 ^{cdefgh}	176.13^{abcdef}	195.25^{efghi}	21.25^{bcde}
Acc106564	11^{abc}	4.3938 ^{efghijk}	156.25^{bcdefg}	138.13^{i}	19.875^{cde}
Acc201067	11^{abc}	5.3750 ^{cdefgh}	135^{defg}	212.38^{cdefgh}	18.75^{cde}
Acc203241	11.5^{ab}	4.5438 ^{efghijk}	148.75^{cdefg}	216.38^{bcdefgh}	21^{bcde}

Acc 212534	10.5^{bc}	7.9288 ^{ab}	226.25^{a}	243.5^{abcde}	19.375^{cde}
Acc 212631	10^{cd}	6.2188^{bcde}	160.25^{bcdefg}	223.75^{abcdefg}	25.875^{abc}
Acc219627	11.5^{ab}	5.0438^{defghi}	202.5^{abc}	290^{a}	23.500^{abcd}
Acc21963	10.5^{bc}	6.8563 ^{abcd}	147.63^{cdefg}	202.38^{cdefghi}	28.250^{ab}
Acc219645	11.5^{ab}	4.8375 ^{efghij}	152.13^{cdefg}	226.88^{abcdefg}	18.75^{cde}
Acc 219647	10^{cd}	5.6750 cdef	106.5^{g}	162.25^{ghi}	17.25^{de}
Acc219648	12^{a}	5.4438^{cdefgh}	125.88^{fg}	148^{hi}	16.5^{de}
Acc219650	12^{a}	5.5438^{cdefg}	156.63^{bcdefg}	189.5^{efghi}	19.5^{cde}
Acc219653	12^{a}	5.0625 ^{defghi}	173^{abcdef}	198.75^{defghi}	15.375^{de}
Acc219654	11^{abc}	3.7938^{fghijk}	137.75^{defg}	241.75^{abcde}	19cd^{e}
Acc219662	11.5^{ab}	6.9438 ^{abcd}	153.88^{cdefg}	191.25^{efghi}	15.75^{e}
Acc219665	11^{abc}	3.8813^{fghijk}	160.25^{bcdefg}	225.75^{abcdefg}	25.375^{abc}
Acc219668	12^{a}	5.0313^{defghi}	157.75^{bcdefg}	271.75^{abc}	21.875^{abcd}
Acc219671	11.5^{ab}	5.3625^{cdefgh}	177.13^{abcdef}	270.13^{abcd}	21.125^{bcde}
Acc219673	12^{a}	2.9688^{jk}	161.63^{bcdefg}	237.88^{abcdef}	19.25^{cde}
Acc219682	10.5^{bc}	3.6^{ghijk}	128.63^{efg}	194.25^{efghi}	22.125^{abcd}
Mean	11.10938	5.067305	158.2539	206.9922	20.28516
LSD (5%)	1.3637	1.9584	57.637	72.792	7.5808
CV (%)	6.018681	18.89691	17.85761	17.24272	18.28127

Where: DoE=days of emergence, NB=number of primary branch, BL=branch length, PH=plant height, INL=inter-node length

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% significance level according to the LSD test.

4.1.4. Leaf area

Analysis of variance revealed that leaf area was significantly affected by different accessions. According to the result, the value of leaf area ranged from 3547.5 cm^2 (local check) to 12000

cm^2 (Acc 200361) (Table 5). Like that of the results of the above agronomic parameters, this result is possibly found due to the inherent variability that exists within the accessions. The result agreed with kedir (2011) and Sarmah *et al*. (2011) who observed difference in leaf area because of difference in castor genotype.

4.1.5. Fresh leaf yield

The analysis of variance revealed highly significant ($p<0.001$) variation (Appendix 1) in fresh leaf yield among the accessions/treatments. Significantly higher fresh leaf yield (13890.9 kg/ha) was obtained from Acc219668 whereas minimum fresh leaf yield (6115.8 kg/ha) obtained from local check. The difference in fresh leaf yield observed in this experiment was could be due to hereditary variation present in selected castor accessions. Similar study was conducted by Kedir (2011) in Ethiopia, Melkassa and found difference in fresh leaf yield among eight different castor genotypes. Beside Sannappa *et al*. (2016) also observed significant variation in fresh leaf yield among five castor hybrid varieties in India. In addition, Kalantri *et al*. (2007) reported average castor fresh leaf yield of 14,400 Kg/ha.

4.1.6. Disease incidence and severity

During the course of the study brown leaf spot (*Cercospora ricinella)* was a serious problem. Hence, *C. ricinella* disease incidence and severity were recorded. Highly significant ($P<0.001$) difference was observed between castor accessions (Appendix 1). Highest disease incidence (60.36%) and severity (48.205%) was recorded on Acc219662/1 where as lowest incidence (15.64%) and disease severity (9.81%) was recorded on Acc200355 and Acc208950/2 respectively. In local castor accession disease incidence of (20.03%) and severity (14.03%) were recorded (Table 5). The difference in disease response is may be due to the genetic variation in disease resistance ability of those accessions. Similarly, Sarmah *et al*.(2011) observed higher disease severity of *Alternaria Leaf spot* (25%) in Acc30 and *Cercospora Leaf blight* (73%) in Acc20 and lower severity in Acc04 (11.5%) and (35.5%) respectively.

On the other hand Lopes *et al*. (2014) in their study to evaluate castor bean genotypes sown in winter and summer at low altitude in Brazil, reported that among ten genotype of castor G1

stood out for the low incidence of gray mold which is economically important disease affecting castor plants in many regions of Brazil.

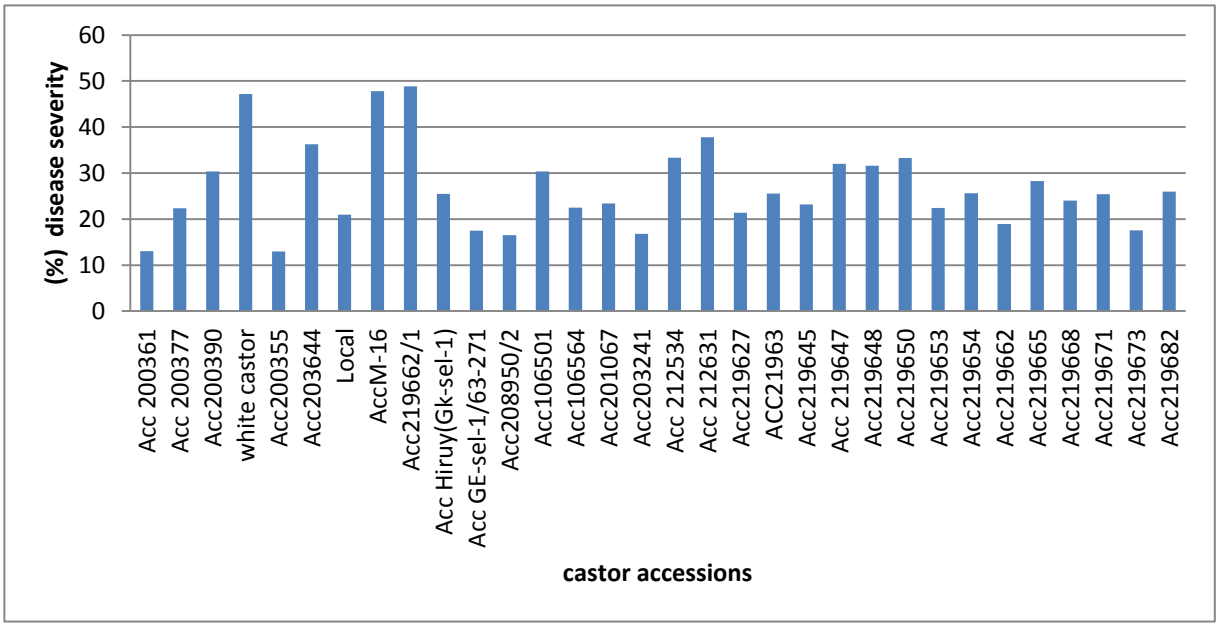

Fig. 2. Severity of brown leaf spot diseases in different castor accessions

Table 5. Agronomic performance (LA & FLY) and Leaf spot disease reaction of different castor accession, Jimma, 2015/2016

Castor Accessions	LA(cm^2)	FLY(kg/ha)	DI (%)	DS (%)
Acc 200361	12000^{a}	13472.2^{b}	14.650^{mno}	13.03^{kl}
Acc 200377	5011.4^{no}	10928^{hi}	$25.56g^{hijkl}$	22.38^{hijkl}
Acc200390	5490.8^{m}	10370.7^{jk}	33.18^{efg}	30.35^{cdefg}
white castor	6310.8^{k}	8132.3^{no}	48.805^{bc}	47.82^{ab}
Acc200355	9724.2^{ef}	8194.3^{lm}	15.64^{klmno}	12.955^{l}
Acc203644	6922.7^{ij}	12334.9^{ef}	39.62^{cde}	36.225^{cd}
Local	3547.5^{q}	6115.8^{r}	14.03^{no}	20.96^{hijkl}
AccM-16	5484.5^{mn}	8766.1^{lm}	50.11^{ab}	47.83^{ab}
Acc219662/1	11008.6^{b}	1255.7^{de}	60.36^{a}	48.205^{a}
Acc Hiruy(Gk-sel-1)	4592.4^{op}	10485.3^{jk}	32.18^{efghi}	25.48^{efghij}
Acc GE-sel-1/63-271	11435^{b}	13628.6^{ab}	14.995^{mno}	17.475^{jkl}

Acc208950/2	4369.5^{p}	90391.1^{l}	9.18^{o}	16.5^{jkl}
Acc106501	5057.1^{no}	10293.9^{k}	31.43^{efghij}	30.35^{cdefgh}
Acc106564	7706.2^{h}	11342.1^{g}	23.175^{hijklmn}	22.48^{fghijk}
Acc201067	7425.9^{hi}	8691.9^{m}	22.23^{ijklm}	23.38^{efghij}
Acc203241	8499.1^{g}	9064.2^{l}	14.16^{no}	16.775^{jkl}
Acc 212534	10290.4^{cd}	13126^{c}	27.98^{ghijk}	33.35^{cde}
Acc 212631	8761.9^{g}	13485.4^{b}	50.45^{ab}	37.76^{c}
Acc219627	5725.9^{l}	13541.9^{b}	16.2^{klmno}	21.38^{ghijk}
ACC21963	6073.7^{kl}	7415.5^{q}	36.5^{def}	25.52^{efghij}
Acc219645	6528^{jk}	12310.9^{ef}	25.01^{ghijkl}	23.155^{efghijk}
Acc 219647	5392.2^{n}	10698.6^{ij}	35.63^{defg}	32.035^{cdef}
Acc219648	7521.8^{h}	1643.8^{pq}	28.618^{fghij}	31.57^{cdefg}
Acc219650	11169.9^{b}	10485.2^{jk}	45.55^{bcd}	33.25^{cde}
Acc219653	9323.5^{f}	12858.4cd	30.865^{efghi}	22.43^{fghijk}
Acc219654	10475.8^{c}	101986.6^{l}	25.56g^{hijklm}	25.63^{efghi}
Acc219662	9840.4^{def}	12815.8^{cd}	15.455^{klmn}	18.925^{ijkl}
Acc219665	6217.7^{kl}	11264.3^{gh}	22.85^{hijklmn}	28.27^{cdef}
Acc219668	10250.4^{cde}	13890.9^{a}	18.670^{jklmn}	23.99^{efghij}
Acc219671	7397.7^{hi}	7850.3^{op}	39.6^{cde}	25.4^{efghij}
Acc219673	6071.1^{kl}	111928^{hi}	17.49^{klmno}	17.56^{jkl}
Acc219682	8482.9^{g}	12097.4^{f}	23.56^{hijklmn}	26efghij
Mean	7628.381	10759.02	28.35297	26.85656
LSD (5%)	527.15	342.54	10.759	10.357
CV (%)	3.388224	1.561020	18.60608	18.90926

Where: LA=leaf area, FLY=fresh leaf yield, DS=disease severity, DI=disease incidence

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% significant level according to the LSD test.

4.2. Biochemical Composition of Castor Accessions

Foliar biochemical compositions have shown significant variations among the various castor accessions. All castor accessions differed significantly from one another with respect to biochemical characters considered in this study. The results obtained are presented and discussed below.

4.2.1. Proximate Nutrient Composition of Castor Accessions

4.2.1.1. Moisture content

Analysis of variance revealed that there was significant ($P<0.01$) variation in leaf moisture content among castor accessions (Appendix 2). The higher moisture content was recorded in the leaf of Acc 200361 (83.135%) followed by Acc201067 (82.71%), Acc203644 (82.07%), Acc200390 (81.945%) and Acc219665 (81.22%) while, the least moisture content was obtained from Acc 200377 (70.09%) and the local (73.87%) castor accession was the second least in moisture content next to Acc 200377 (Table 6). These results are in conformity with the observations of Sannappa and Jayaramaiah (2002) and Chandrappa *et al.* (2005) who observed variations in moisture content of leaves among the castor genotypes

Also earlier studies of Manjunath and Sannappa, (2012) in Western Ghats of Karnataka, India indicated significant variations in leaf moisture content in different castor genotype. They recorded higher moisture content in KJ000406 accession (75.42%) and lower in KJ130048 accession (62.60%). In addition Sarmah *et al*. (2011) observed significantly different moisture content among eight different castor accessions that varied from 26.83% (Acc56) to 79.32% (Acc04).

The increase in leaf moisture content in fewer genotypes might be enhancement of hydrogen ion concentration in plant sap due to accumulation of chlorides and less moisture loss by evapo-transpiration in the leaves (Eaton, 1942).

4.2.1.2. Percentage ash content

Ash content of leaves showed significant variation (P<0.001) among castor accessions (Appendix 2). The highest ash content (22.9%) was recorded from the leaves of Acc 219647 while the lowest ash (15.385%) was recorded from Acc219662/1. However, the local check was equivalent with Acc219671 in ash content (21.95%) but lower than Acc 219647 (22.9%) and Acc219645 (22.21%) (Table 6). The variation in ash content was may be due to the variation in genetic constitution of different castor accession. Similarly, Kedir, (2016) observed significant variation in ash content between eight different castor genotypes. Even in the same plant species but different variety, ash content may vary due to variation in metal composition (Selema and Farago, 1996).

4.2.1.3. Crude protein

The analysis of variance showed that there was significant variation in leaf crude protein content between castor accessions (Appendix 2). The highest crude protein (24.412%) estimated was from leaves of Acc219662/1 followed by Acc 200361 (23.984%) but, the lowest (7.967%) was from Acc 219647. In addition, the local check (19.972%) was good in crude protein content as compared to those castor accessions (Table 6). The variation in crude protein content might be due to difference in genetic variation between castor accessions.

Similar observations were reported by Sannappa and Jayaramaiah (2002); Chandrappa *et al.* (2005); Sarmah *et al*. (2011); Manjunath and Sannappa (2012) and Chandrashekhar *et al*. (2013) they observed different crude protein content because of difference in castor genotype and accession.

Adjolohoun *et al.* (2013) in their study of Variety and environmental effects on crude protein concentration and mineral composition of *Arachis pintoi* in two sites of Benin, West Africa they reported that crude protein concentrations depends on both genetic characteristics of varieties and plant environment. In addition, they observe variation in crude protein content in the same site but different variety.

4.2.1.4. Crude fiber

There was significant variation in crude fiber content. The maximum crude fiber content was recorded in the leaves of Acc 219647 (24.005%) while, the minimum was from Acc219662 (13.070%). The local check fiber content (14.761%) was less than the fiber content of twenty seven castor accession except Acc219662 (13.070%), Acc219662/1 (13.46%), Acc219627 (13.725%), Acc 200361 (14.385%) and Acc 212534 (14.405%) (Table 6).The variation in crude fiber content may be due to variation in castor accession. This finding is supported by the finding of Kedir (2016) who recorded minimum crud fiber in Abaro (17.64 %) and maximum in GK sel (21.58 %) from eight castor genotypes. Also Sarmah *et al*. (2011) observes significantly higher fiber content in Acc36 and minimum in Acc03. The variation in fiber content among different accession could be attributable for their inherent characters.

4.2.1.5. Crude fat

There was significant variation in crude fat content of the leaves among treatments/ accessions. According to analysis of variance the highest fat content (1.262%) was recorded from Acc200361 followed by Acc219662/1 (0.9355%) and the lowest (0.3205%) was recorded from Acc201067. This finding is supported by the finding of Sarmha (2011); Kedir (2014) who observed variation in fat content among castor genotype. The difference in crude fat content in the present study may be due to the inherited variation existed among castor accessions.

4.2.1.6. Total carbohydrate

Significant variations were noticed for total carbohydrate content among the leaves of castor accessions. Acc200355 recorded highest (52.149%) carbohydrate content. Whereas, the lowest amount of 42.983% and 42.698% carbohydrate was recorded from the local check and Acc219648, respectively. The present observations is in agreement with the findings of Sannappa and Jayaramaiah (2002) and Govindan *et al.* (2003a and 2003b) and Chandrappa *et al.* (2005) who also observed variation in the total carbohydrate content among the castor

genotypes. The variation in total carbohydrate may be due to the genetic difference present among castor accessions.

4.2.2. Proximate Mineral Composition of Castor Accessions

4.2.2.1. Nitrogen content

The compositions of leaf mineral (nitrogen) have also shown highly significant ($P \leq 0.001$) variation among castor accessions (Appendix 2). As it can be observed from the trend of crude protein, the nitrogen content of the leaf for castor accessions was significantly different. Nitrogen content was high in Acc219662/1 (3.898%) closely followed by Acc 200361 (3.8375%) but, low in Acc 219647 (1.275%). The variation in nitrogen content of the leaves may be due to the differences in genetic constitution of different castor accession. This result is in agreement with the finding of Kedir (2011); Sarmah *et al*. (2011); Chandrashekhar *et al.* (2013) who observed significant difference among castor genotype in terms of nitrogen content.

4.2.2.2. Phosphorus content

Phosphorus content of leaves showed significant variation ($P<0.001$) among castor accessions (Appendix 2). Phosphorus content of the leaves ranged from 1.997% in Acc 200361 to 0.64% in Acc219665. But, the local check castor showed minimum (0.655%) phosphorus content but higher than Acc219665. The difference observed in phosphorus content of the leaves is maybe due to the genetic variation which existed among castor accession. The present findings support the idea of Kedir (2011) who observes variation in phosphorus content among castor genotype because of genetic variability among them. Similarly, early study of Chandrashekhar *et al.* (2013) in Bangalore district, India also observed significantly higher (0.396%) phosphorus content in Local castor genotype and lower (0.125%) in DCH-177 among eight castor genotype.

Table 6. Proximate nutrient and mineral composition of castor accessions, Jimma, 20015/2016

Castor Accessions	Nitrogen (%)	Protein (%)	Ash (%)	Fiber (%)	Moisture (%)	Fat (%)	Carbohydrate (%)	Phosphorus (%)
Acc 200361	3.8375^{ab}	23.984^{ab}	16.935^{klm}	14.385^{jkl}	83.135^{a}	1.262^{a}	43.434^{fgh}	1.997^{a}
Acc 200377	1.4595^{no}	9.122^{mn}	21.89^{abc}	23.28^{ab}	70.9^{j}	0.387^{hijk}	45.322^{defgh}	0.8955^{ijklmno}
Acc200390	1.54^{no}	9.625^{mn}	20.705^{bcdefg}	20.961^{bcd}	81.945^{abcd}	0.335^{k}	48.375^{abcd}	1.0605^{ghijk}
white castor	1.632^{lmno}	10.2^{klmn}	19.06^{ghij}	20.086^{cdef}	80.95^{abcde}	0.37^{ijk}	50.285^{ab}	1.365^{bcdef}
Acc200355	2.2915^{ij}	14.322^{hi}	16.45^{klm}	16.385^{ghij}	77.670^{cdefghi}	0.695^{def}	52.14^{a}	1.52^{bc}
Acc203644	2.361^{hij}	14.6g^{hi}	18.895^{hij}	18.185^{fgh}	82.07^{abc}	0.739^{cde}	47.425^{bcdef}	1.0035^{hijkl}
Local	3.1955^{cde}	19.972^{cde}	21.95^{ab}	14.761^{jkl}	73.87^{ij}	0.335^{k}	42.983^{gh}	0.6550^{no}
AccM-16	2.407^{hij}	15.044^{ghi}	19.05^{ghij}	18.125^{fghi}	79.335^{abcdefg}	0.526^{fghij}	47.256^{bcdef}	0.922^{ijklmn}
Acc219662/1	3.898^{a}	24.421^{a}	15.385^{m}	13.46^{kl}	78.4^{bcdefghi}	0.9355^{b}	45.799^{cdefg}	1.836^{a}
Acc Hiruy(Gk-sel-1)	1.584^{mno}	9.9l^{mn}	20.69bcdefg	21.131^{bcd}	78.72^{abcdefgh}	0.7425^{cde}	47.538^{bcdef}	1.255^{cdefgh}
Acc GE-sel-1/63-271	1.9175^{jklm}	11.984^{ijklm}	21.105bcdef	21.643^{abc}	78.195^{bcdefghi}	0.5705^{efgh}	44.698^{defgh}	0.965^{ijklm}
Acc208950/2	2.2125^{ijk}	13.828^{hij}	21.2bcde	19.538^{cdef}	82.12^{abcde}	0.6465^{def}	44.789^{defgh}	0.819^{klmno}
Acc106501	2.1^{ijklm}	13.125^{hijk}	20.11defg	20.764^{bcde}	77.705^{cdefghi}	0.685^{def}	43.816^{fgh}	1.255^{cdefgh}
Acc106564	1.731^{klmn}	10.819^{jklmn}	21.685abcd	20.982^{bcd}	76.935^{efghi}	0.355^{ijk}	46.194^{bcdefg}	0.799^{klmno}
Acc201067	2.5015^{fghi}	15.634^{fgh}	19.575^{efghi}	18.3^{efgh}	82.71^{ab}	0.3205^{k}	46.171^{bcdefg}	0.6995^{mno}
Acc203241	3.2905^{bcde}	20.566^{bcde}	16.48^{klm}	16.585^{ghij}	77.97^{cdefghi}	0.905^{bc}	45.465^{defgh}	1.15^{efghi}

Acc 212534	3.0450^{def}	19.988^{cde}	16.28^{lm}	14.405^{jkl}	77.67^{cdefghi}	0.6465^{def}	48.681^{abcd}	1.541^{b}
Acc 212631	2.908^{efgh}	18.175^{efg}	17.717^{jkl}	16.775^{ghij}	77.98^{cdefghi}	0.656^{def}	46.678^{bcdefg}	1.105^{ghij}
Acc219627	3.548^{abcd}	22.175^{abcd}	16.785^{klm}	13.752^{kl}	80.68^{abcdef}	0.904^{bc}	46.412^{bcdefg}	1.3265^{bcdefg}
Acc21963	2.608^{fghi}	16.3^{fgh}	17.94^{ijk}	15.35^{jkl}	79.79^{abcdefg}	0.539^{fghi}	49.681^{abc}	0.8575^{jklmno}
Acc219645	1.545^{no}	9.656^{mn}	22.21^{a}	20.781^{bcde}	74.57^{hi}	0.35^{jk}	46.314^{bcdefg}	1.065^{jhijk}
Acc 219647	1.275^{o}	7.969^{n}	22.9^{a}	24.005^{a}	75.175^{ghij}	0.372^{ijk}	44.445^{efgh}	0.795^{mno}
Acc219648	3.5380^{abcd}	22.113^{abcd}	19.145^{ghij}	15.585^{ijkl}	76.645^{efghi}	0.46^{ghijk}	42.698^{h}	1.45^{bcd}
Acc219650	3.273^{cde}	20.453^{cde}	19.46^{fghi}	15.075^{jkl}	77.37^{defghi}	0.60^{efg}	44.412^{efgh}	1.25^{defgh}
Acc219653	3.0355^{defg}	18.972^{de}	15.745^{m}	15.975^{hijk}	78.44^{bcdefghi}	0.677^{def}	48.632^{abcd}	0.824^{klmno}
Acc219654	2.581^{fghi}	16.131^{fgh}	19.25^{ghij}	18.3^{efgh}	77.04^{efghi}	0.75^{cde}	45.504^{defgh}	1.001^{ijkl}
Acc219662	3.6405^{abc}	22.175^{abc}	16.795^{klm}	13.070^{l}	79.595^{abcdefg}	0.375^{ijk}	47.227^{bcdef}	1.38^{bcde}
Acc219665	2.495^{ghi}	15.594^{fgh}	18.07^{ijk}	18.72^{defg}	81.22^{abcde}	0.39^{hijk}	47.227^{bcdef}	0.64^{o}
Acc219668	2.18^{ijkl}	13.625^{hijk}	20.965^{bcdef}	20.2^{cdef}	76.05^{fghi}	0.7425^{cde}	44.463^{efgh}	1.3155^{bcdefg}
Acc219671	2.2535^{ijk}	14.178^{hij}	21.95^{ab}	19.521^{cdef}	79.265^{abcdefg}	0.425^{ghijk}	43.927^{fgh}	1.435^{bcd}
Acc219673	2.222^{ijk}	13.887^{hij}	20.235^{cdefg}	20.281^{cdef}	79.775^{abcdefg}	0.601^{efg}	44.996^{defgh}	1.1365^{efghi}
Acc219682	1.5685^{mno}	9.816^{lmn}	21.755^{abcd}	23.135^{ab}	77.445^{cdefghi}	0.8155^{bcd}	44.476^{efgh}	0.917^{ijklmn}
Mean	2.489844	15.59627	18.23547	19.35522	78.44797	0.597438	46.16983	1.132688
LSD (5%)	0.5483	3.4456	1.6565	2.5594	4.6512	0.1835	4.1477	0.2677
CV (%)	10.79656	10.83237	4.19626	6.881763	2.907062	15.06039	4.404775	11.58995

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.3. Effect of Different Castor Accessions on Rearing Performance of Eri-Silkworms

In this experiment, there were significant variations in all silkworm traits when eri-silkworms were fed on different castor accession. The results of silkworm rearing characters fed on different castor accessions are discussed below.

4.3.1. Larval traits

4.3.1.1. Larval duration

Significant variations were evident in respect to larval duration of each treatment. Shorter larval duration (17.5 days) was noticed in the silkworms fed with Acc 200361 and Acc 212534. Longer larval duration (21.0 days) was recorded in the silkworms fed with Acc200355, Acc208950/2, Acc201067, Acc219645 and Acc219673. Similar observations were reported by Jayaramaiah and Sannappa (2000a); Govindan *et al.*(2002a; 2002b); Hazarika *et al.*(2003); Ramakrishna *et al.*(2003); Sannappa *et al* .(2007); Dasari *et al.(*2013) and Rajasri and Lakshmi (2015) who observed different larval duration among silkworms because of difference in castor genotypes. The variation observed in silkworms that fed on different accession of castor might be due to the fact that these castor accessions vary in their composition of foliar constituents, discussed above which in turn contribute for differences in larval characters including larval duration.

In addition, the larval duration in the second rearing was longer as compared to the first rearing. This might be due to leaf nutrient content. The shorter larval duration (18.5 days) was recorded in silkworms fed with Acc 200361, Acc 212534 and Acc 212534 and longer larva duration (22.0 days) was observed on Acc201067, Acc208950/2 and Acc219645. Eri-silkworms fed on local castor accession showed (20.0 days and 20.5 days) of larval duration in the first and second rearing, respectively. In accessions which had good composition of minerals and nutrients in their leaves silkworms got the required amount of nutrients that are used for silk production and it lead them to maturity in a short period of time. In sericulture industry shorter larval duration is important. As larval duration become shorter cocoon production per year increases.

4.3.1.2. Matured larvae weight

Similarly, significant variation was noticed in matured larval weight when eri-silkworms were fed with thirty two castor accessions. Larvae attained 7.6 gm and 7.4 gm of mature larval weight when fed with Acc 200361 and Acc219654 whereas, lower weight of 5.6 gm was observed with Acc219665 and Acc200390. The variation in matured larva weight in the present study might be due to the effects of different castor accession which might have influence on larva weight of eri-silkworm .This result is concur with the finding of Kedir *et al.* (2013) who obtained larval weight of 8.20 gm and 8.17 gm in selected castor genotype called Bako and Abaro respectively in Ethiopia.

Similarly, Sannappa *et al*. (2007) observed that from twelve castor genotype worms fed on leaves of RC-8 castor genotype recorded significantly higher mature larval weight (67.53 gm/10 larvae) whereas worms fed on DCS-9 shows significantly lower mature larval weight (47.98 gm/10 larvae). Also Patil *et al.* (2000), Chandrashekhar *et al*. (2012) and Dasari *et al*. (2013) are in conformity with these observations. Sarkar *et al*. (2015) stated that food quality may reduce the actual performance of an insect below its physiological potential. The variation observed in larval weight may be due to the foliar constituents of the castor accessions.

Furthermore, the weight of matured larva got decreased in the second rearing. The highest recorded larval weight from the second rearing was (5.6 gm) from larvae fed with leaves of Acc200361 and the lowest larval weight was recorded from Acc200390 and Acc219665 (3.6 gm). Silk worms fed on local castor accession leaves showed medium larval weight of 6.9 gm and 4.9 gm in the first and second rearing respectively when compared with the other accessions. Larval weight of the second rearing when compared with the first rearing was decreasing. The decrease in larval weight may be due to nutrient composition of the leaf. In the second rearing the castor accessions got more matured and showed flower and seed setting. The nutrients synthesized during reproductive and maturity stage of flowering plants including castor is normally translocated from the leaf to the reproductive tissue such as seed development leading to over matured less palatable leaves for silkworm rearing. Under such circumstances the silkworm fed with such leaves shows retarded growth and development.

Minerals are exported from the leaves to the seeds during seed development to contribute nutrient to seeds (Uauy *et al*., 2006; Sankaran and Grusak, 2014).

4.3.1.3. Fecundity

Silkworm fed on Acc 200361 showed significantly higher fecundity (351.45 eggs/female) followed by Acc 212534 (345 eggs/female). The lowest fecundity (116 eggs/ female) was recorded in the warms that fed on Acc208950/2 followed by (113 eggs/female) in Acc106501. The second rearing was conducted two month after the first rearing. In the second rearing there was also significant variation in terms of fecundity. The highest fecundity (345 eggs/female) was recorded on the larvae fed on Acc 20036. On the other hand, worms fed on Acc106501 leaves showed the lowest fecundity (108 eggs/female). The fecundity recorded on larvae's fed on local check was (191.5 eggs/female and 186.85 eggs/ female) in the first and second rearing respectively. It is compared with the finding of Sannappa *et al.* (2007) who obtained fecundity of 346.67 eggs/laying in selected castor genotype called Aruna in India. Earlier study of Sarkar *et al*. (2015) from Assam, India also observed highest fecundity (325 eggs/female) from worms fed on Acc. 003 and the lowest fecundity (301 eggs/female) from Acc. 056. The oviposional behavior of eri-silkworm varies with respect to feeding of different accessions of castor which in turn has an impact on fecundity (Sarkar *et al*., 2015).

Variations were also observed between the first and second rearing. In the second rearing fecundity of all treatments was decreased as compared to the first rearing. The observed reduction in fecundity in the second rearing might be due to reduction in nutrient content of the leaf because the second rearing was conducted during flowering and seed setting of the plant. As a result, there is translocation of nutrient from the leaf to fruits.

4.3.1.4. Hatchability

There were significant differences in hatchability of eri-silkworms. Hatching percentage of silkworm larvae fed on different castor accessions showed significant variation ($p<0.01$) (Appendix 3 Table 1). Silkworm fed on Acc201067 showed significantly higher hatching percentage (96.75%) followed by Acc Hiruy (Gk-sel-1) and Acc 200361 (96.5%). The local

check castor accession which was medium performer as compared to the other accessions was the lower in hatching percentage (88.25%). This finding is supported by the finding of Sarkar *et al*. (2015) who observed maximum hatching percentage (90%) from Acc03 and minimum hatching percentage (85%) from Acc056 as a result of castor genotypic difference. Also Sannappa *et al.* (2007) observed maximum (98.92%) and minimum (98.05%) hatching percentage from different castor genotypes, Aruan and DCS-9, respectively. This variation in hatching percentage might be due to different factors such as environmental condition and variation in castor genotype. Foliar constituents of castor genotypes has direct correlation with hatchability of eri-silkworms (Chandrashekhar and Govindan, 2010; Sarkar *et al*., 2015).

4.3.1.5. Survival rate

Non-significant ($P > 0.05$) difference was found with regard to Survival rate resulted from feeding of worms with different castor accessions separately in both rearing time (Appendix 3 Table 1&2). This shows that all accessions studied in this experiment were found to be equally important for survival of the silkworms. Sannappa *et al*, (2007) also observe non-significant difference in terms of survival rate when silkworms fed on different castor genotype. On the contrary, this result is disagree with the finding of kedir (2013) who observed variation in survival rate due to difference in castor genotype. The observed variation between the two study might be due to the varietal and environmental difference existed between the two studies.

Table 7. Rearing performance of Eri-silkworm fed with different castor accessions, at Jimma, 2015/2016.

	First rearing				Second rearing			
Castor Accessions	Larva duration (days)	Mature larval weight(gm)	Fecundity (no.)	Hatchability (%)	Larva duration (days)	Mature larval weight(gm)	Fecundity (no.)	Hatchability (%)
Acc 200361	17.5^{g}	7.6^{a}	351.45^{a}	96.5^{a}	18.5^{g}	5.6^{a}	345^{a}	96.5^{a}
Acc 200377	19^{de}	6.1^{kl}	217.55^{i}	96.5^{a}	$20d^{e}$	4.1^{l}	212.25^{fgh}	96.5^{a}
Acc200390	19^{de}	5.6^{m}	133.75^{s}	96.0^{abc}	$20d^{e}$	3.6^{m}	128.9no	96^{abc}
white castor	20^{bc}	7.0^{cdef}	269.4^{d}	95.25^{abcde}	21^{bc}	5.0^{def}	264.2c	95.25^{abcde}
Acc200355	21^{a}	7.0^{cdef}	262.05^{e}	96.15^{ab}	21.5^{ab}	5.0^{def}	257.05^{cd}	9.615^{ab}
Acc203644	19^{de}	6.4^{ijk}	234.8^{g}	95.15^{abcdef}	20^{de}	4.4^{lk}	229.75^{defg}	95.15^{abcde}
Local	20^{bc}	6.9^{defg}	191.5^{m}	88.25^{k}	20.5^{cd}	4.9^{efg}	186.85^{hijk}	88.25^{k}
AccM-16	18^{fg}	6.7^{fghi}	211.5^{j}	94.9^{abcdef}	19^{fg}	4.7^{ghi}	206.5^{gh}	94.9^{abcdef}
Acc219662/1	19^{de}	6.5^{hij}	195.15^{m}	96.3^{ab}	20^{de}	4.5^{ij}	190.40^{hijk}	96.3^{ab}
Acc Hiruy(Gk-sel-1)	20^{bc}	6.7^{fghi}	208.75^{j}	96.5^{a}	21^{bc}	4.7^{ghi}	203.85^{ghi}	96.5^{a}
Acc GE-sel-1/63-271	20^{bc}	6.55^{ghij}	150.3^{q}	95.55^{abcd}	21^{bc}	4.55^{hij}	145.10^{mn}	95.55^{abcd}
Acc208950/2	21a	6.2^{jk}	116^{t}	93.5^{defgh}	22^{a}	4.2^{kl}	111.25^{o}	93.5^{cdefg}
Acc106501	19^{de}	7.2^{bcd}	113.0^{t}	93.1^{efghi}	20^{de}	5.2^{bcd}	108.00^{o}	93.1^{efghi}
Acc106564	20.5^{ab}	7.3^{abc}	193.5^{m}	95.5^{abcd}	21.5^{ab}	5.3^{bc}	193.55^{hijk}	95.5^{abcd}
Acc201067	21^{a}	7.0^{cdef}	343.75^{b}	96.75^{a}	22^{a}	5.3^{bc}	316.00^{ab}	96.75^{a}

Acc203241	19de	7.2^{bcd}	249.65^{f}	92.9^{fghi}	20de	5.0^{def}	244.05^{cde}	92.9^{fghi}
Acc 212534	17.5^{g}	6.9^{defg}	345.95^{b}	94.5^{abcdefg}	18.5^{g}	5.4^{ab}	321.45^{ab}	94.5^{abcdefg}
Acc 212631	19de	7.0^{cdef}	180.7^{n}	93.8^{cdefgh}	20de	5.0^{def}	175.60^{ijkl}	93.8^{cdefg}
Acc219627	18.^{5ef}	6.8^{efgh}	246.8^{f}	96.5^{a}	19.5^{ef}	4.8f^{gh}	241.6^{cdef}	96.5^{a}
Acc21963	20^{bc}	6.5^{hij}	263.95^{e}	95.1^{abcdef}	21^{bc}	4.5ij	208.65^{gh}	95.1^{abcde}
Acc219645	21^{a}	6.9^{defg}	235.425^{g}	96.25^{ab}	22^{a}	4.9^{efg}	229.75^{defg}	96.25a
Acc 219647	18^{fg}	7.4^{ab}	203.5^{k}	90.1^{jk}	19.5^{de}	5.4^{ab}	199.1^{hij}	90.1^{ij}
Acc219648	19de	6.8^{efgh}	177.5^{n}	93.2^{efghi}	20d^{e}	4.8^{fgh}	172.3^{jklm}	93.2^{efghi}
Acc219650	20.5^{ab}	5.8^{lm}	302.9^{c}	95^{abcdef}	21^{bc}	3.8^{m}	297.9^{b}	95^{abcde}
Acc219653	19d^{e}	6.1^{kl}	220.3^{hi}	92.25^{ghij}	20de	4.1^{l}	215.3^{efgh}	92.25^{ghij}
Acc219654	19d^{e}	7.4^{ab}	223.325^{h}	95.5^{abcd}	20de	5.4^{ab}	208.20^{gh}	95.5^{abcd}
Acc219662	19.5^{cd}	6.7^{fghi}	199.25^{l}	95.65^{abcd}	21^{bc}	4.7^{ghi}	194.40^{hijk}	95.65^{abcd}
Acc219665	19de	5.6^{m}	172.05^{o}	95.9^{abc}	20de	3.6^{m}	166.95^{klm}	95.9^{abc}
Acc219668	18.5^{ef}	6.5^{hij}	149.125^{q}	94.15^{bcdefgh}	19.5^{ef}	4.5^{ij}	144.00^{mn}	94.15^{cdefgh}
Acc219671	20^{bc}	7.1^{bcde}	152.125^{q}	91.25^{ij}	21^{bc}	5.1^{cde}	147.15^{lmn}	91.25^{ij}
Acc219673	21^{a}	6.9^{defg}	158.65^{p}	92^{hij}	21.5^{ab}	4.9^{efg}	153.75^{lmn}	92^{hij}
Acc219682	18^{fg}	6.4^{ijk}	141.75^{r}	93.5^{defghi}	20de	4.4^{jk}	136.60^{no}	93.5^{defgh}
Mean	19.39063	6.710938	212.9828	94.48281	20.35938	4.726563	204.8578	94.48281
LSD (5%)	0.6714	0.3813	3.7677	2.2627	0.6714	0.3813	29.688	2.2627
CV (%)	1.72115	2.785924	0.867365	1.174217	1.868124	2.887294	7.105657	1.174217

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.3.2. Cocoon traits

4.3.2.1. Effective rate of rearing, ERR (%)

Percentage ERR showed significant variation when eri-silkworms were fed on different castor accessions. It varied from 82.5% (minimum) to 98.6% (maximum). Larva fed on Acc 200361 showed maximum ERR (98.6%) followed by Acc 212534 (98.5%). The least ERR was recorded from larvae fed on Acc 200377, Acc219662 and Acc219665 (82.5%) (Table 8).The variation in ERR of silkworm fed with different castor accessions may be due to the differences in foliar composition and nutrients availability in different accession which contribute to the growth and development of silk worms. Similar findings were reported by Chandrashekhar and Govindan (2010); Kedir *et al.* (2013); Dasari *et al*. (2013) in all cases, they observed variations in ERR because of variations in castor genotypes.

4.3.2.2. Single cocoon weight, single shell weight and percentage shell ratio

Cocoons formed by the worms fed on leaves of selected castor accession exhibited significant ($p<0.001$) variation in cocoon traits in the first rearing (Table 8 & Appendix 3 Table 1). Significantly, higher single cocoon weight (3.55 gm) and shell weight (0.509 gm) were recorded from larvae fed on Acc 200361. However, the higher shell ratio (14.585%) was recorded from Acc Hiruy(Gk-sel-1) closely followed by Acc219645(14.455%), Acc201067(14.375%), Acc219647(14.37%) and Acc 200361(14.33%). On the contrary, lower cocoon weight (2.500 gm), shell weight (0.307 gm) and shell ratio (12.315%) was recorded from larvae fed on leaves of Acc219662. The worms fed on local check scored medium cocoon weight (3.2 gm), shell weight (0.4015 gm) and lower shell ratio (12.54%) as compared to other accessions. On the other hand, in the second rearing the higher cocoon weight (2.7 gm), shell weight (0.364 gm) and shell ratio (13.465%) were recorded from worms fed on Acc 200361 and the lowest cocoon weight (1.9 gm), shell weight (0.201gm) and shell ratio (10.575%) was recorded from local check. These results are in agreement with the findings of Patil *et al.* (2000); Pandey (2003) and Ahmed *et al.* (2015) who recorded variation in cocoon traits when different castor genotypes offered as food. Moreover, Sarkar *et al.* (2015) obtained significant variation in cocoon traits when eri-silkworms were reared on

different castor genotype in India. In the present findings, pooled analysis of highest cocoon weight (3.38 gm), shell weight (0.51gm) and shell ratio (15.08%) was recorded from Acc003.

The noticed variation in cocoon characters may be a reflection of the nutritional status of the castor accessions as evidenced by the positive and significant correlation coefficients worked out between the foliar constituents and eri-silkworm cocoon traits. Many previous workers have reported such significant correlation between castor leaf nutritional status and eri-silkworm cocoon traits (Chandrappa *et al.*, 2005; Sannappa *et al*., 2007; Sarmah *et al.*, 2011; Jayaramaiah and Sannappa, 2000b). In addition Chaudhury (1979) reported that nutritional value of the feed play a major role in larval and cocoon parameters.

Quantitative reduction of cocoon trait in the second rearing might be due to the reduction in nutritional status of more matured leaf and less palatable by the developing worms. The second rearing was done two months after the first rearing and by then the castors plants started already to flower and set seed. Therefore, the nutrients produced in the leaf by and large started to be translocated to the sink, seed development, resulting in to more matured, less palatable and nutrient deficient leaves. Nutrient stored in plant leaves start to be re-traslocated to support seed formation at seed development stage of castor plants (Krishna, 2012). During seed fill, VSP is hydrolyzed and the resulting amino acid products accumulated in leaves are moved symplasmically to the vascular bundles for phloem loading and export to developing seeds (Franceschi *et al*. 1983; Lansing and Franceschi, 2000).

Table 8. Performance of eri-silkworm fed on different castor accessions at Jimma, 2015/2016

	First rearing					Second rearing		
Castor Accessions	ERR (%)	Single Cocoon weight (gm)	Shell weight (gm)	Shell ratio (gm)	ERR (%)	Single Cocoon weight (gm)	Shell weight (gm)	Shell ratio (%)
Acc 200361	98.6^{a}	3.55^{a}	0.509^{a}	14.33^{a}	98.6^{a}	2.7^{a}	0.364^{a}	13.465^{a}
Acc 200377	82.5^{d}	3.2^{bcd}	0.4275^{efghi}	13.32^{def}	82.5^{d}	2.2^{cdef}	0.256^{bcdefgh}	11.875^{bcdefg}
Acc200390	98^{a}	3.4^{ab}	0.4625 ^{bcde}	13.57^{cde}	98^{a}	2.6^{ab}	0.2975^{bc}	11.43^{cdefg}
white castor	95^{abc}	3.3^{abc}	0.453^{bcdefg}	13.75^{bcde}	95^{abc}	2.3^{bcde}	0.2785^{bcdefg}	12.115a^{bcdef}
Acc200355	95.5^{ab}	3.15^{bcde}	0.3915^{i}	12.425^{h}	95.5^{ab}	2.1^{def}	0.2315^{ghi}	10.985^{fg}
Acc203644	97^{a}	3.5^{a}	0.4635^{bcde}	13.235^{efg}	97^{a}	2.6^{ab}	0.3035^{b}	11.625^{bcdef}
Local	92.5^{abc}	3.2^{bcd}	0.4015^{hi}	12.54^{h}	92.5^{abc}	1.9^{f}	0.201^{i}	10.575^{g}
AccM-16	97.5^{a}	3.5^{a}	0.4475^{bcdefg}	12.78^{gh}	97.5^{a}	2.5^{abc}	0.2785^{bcdef}	11.145^{fg}
Acc219662/1	96.5^{a}	3.5^{a}	0.4765^{ab}	13.615^{cde}	96.5^{a}	2.3^{bcde}	0.2815^{bcde}	12.235^{abcdef}
Acc Hiruy(Gk-sel-1)	97^{a}	3.1^{cde}	0.4525^{bcdefg}	14.585^{a}	97^{a}	2.1^{def}	0.2475^{defgh}	11.75^{bcdef}
Acc GE-sel-1/63-271	92.5^{abc}	3.3^{abc}	0.4545 ^{bcdef}	13.76^{bcde}	92.5^{abc}	2.3^{bcde}	0.2895^{bcd}	12.56^{abcd}
Acc208950/2	97^{a}	3.1^{cde}	0.4235^{efghi}	13.33^{def}	97^{a}	2.1^{def}	0.2705^{bcdefgh}	12.895^{ab}
Acc106501	92.5^{abc}	2.8^{f}	0.349^{j}	12.46^{h}	92.5^{abc}	2.1^{def}	0.242^{defghi}	11.5^{cdef}
Acc106564	95^{abc}	3.1^{cde}	0.4285^{defghi}	13.775^{bcd}	95^{abc}	2.1^{def}	0.261^{bcdefgh}	12.74^{abc}
Acc201067	96^{ab}	3.3^{abc}	0.4745^{abc}	14.375^{a}	96^{ab}	2.3^{bcde}	0.276^{bcdefgh}	11.985^{bcdef}
Acc203241	92.5^{abc}	3.5^{a}	0.476^{ab}	13.39^{de}	92.5^{abc}	2.5^{abc}	0.300^{bc}	12.03^{cdef}

Acc 212534	98.5^{a}	3.1^{cde}	0.413^{ghi}	13.325^{def}	97^{a}	2.1^{def}	0.268^{bcdefgh}	12.78^{abc}
Acc 212631	92.5^{abc}	3.1^{cde}	0.437^{bsdefgh}	14.09^{abc}	92.5^{abc}	2.1^{def}	0.251^{cdefgh}	11.975^{bcdef}
Acc219627	97^{a}	3.3^{abc}	0.441^{bcdefgh}	13.365^{def}	97^{a}	2.3^{bcde}	0.256^{bcdefgh}	11.155^{fg}
Acc21963	95^{abc}	3.2^{bcd}	0.425^{efghi}	13.275^{defg}	95^{abc}	2.3^{bcde}	0.270^{bcdefgh}	11.735^{bcdef}
Acc219645	97.5^{a}	3.3^{abc}	0.477^{ab}	14.455^{a}	97.5^{a}	2.2^{cdef}	0.2445^{efghi}	11.025fg
Acc 219647	88^{cd}	3.1^{cde}	0.4455^{bcdefg}	14.37^{a}	88^{cd}	2.1^{def}	0.256^{bcdefgh}	12.115^{abcdef}
Acc219648	96^{ab}	3.3^{abc}	0.45^{bcdefg}	13.665^{cde}	96^{ab}	2.3^{bcde}	0.272^{bcdefgh}	11.845^{bcdef}
Acc219650	89^{bcd}	3.5^{a}	0.4685^{bcd}	13.385^{de}	89bcd	2.5abc	0.2885^{bcd}	11.54^{bcdef}
Acc219653	92.5^{abc}	3.1^{cde}	0.4265^{efghi}	13.75^{bcde}	92.5^{abc}	2.1^{def}	0.237^{efghi}	11.295^{fg}
Acc219654	92.5^{abc}	3.2^{bcd}	0.4345^{cdefgh}	13.57^{cde}	92.5^{abc}	2.1^{def}	0.2455^{defghi}	11.665^{bcdefg}
Acc219662	82.5^{d}	2.5^{g}	0.307^{k}	12.315^{h}	82.5^{d}	2.0^{ef}	0.2275^{hi}	11.375^{defg}
Acc219665	82.5^{d}	3^{def}	0.4275^{efghi}	14.25^{ab}	82.5^{d}	2.0^{ef}	0.2345^{efghi}	11.725^{bcdef}
Acc219668	96^{ab}	3.2^{bcd}	0.416^{fghi}	12.84^{gh}	96^{ab}	2.2^{cdef}	0.243^{defghi}	11.045^{fg}
Acc219671	92.5^{abc}	3^{def}	0.405^{hi}	13.48^{de}	92.5^{abc}	2.0^{ef}	0.2545^{bcdefgh}	12.725^{abcd}
Acc219673	96a^{b}	3.3^{abc}	0.451^{bcdefg}	13.67^{cde}	96^{ab}	2.4^{abcd}	0.282^{bcde}	11.745^{bcdef}
Acc219682	97.5^{a}	2.9^{def}	0.348^{j}	12.425^{h}	97.5^{ab}	2.0^{ef}	0.229^{ghi}	11.45^{cdef}
Mean	93.78438	3.417188	0.507422	14.87594	93.73750	2.231250	0.264061	11.81828
LSD (5%)	7.4496	0.2798	0.06	1.4603	7.4496	0.2798	0.06	1.4603
CV (%)	3.894718	4.015186	5.801148	4.813193	3.894718	6.971104	9.149737	5.637063

LSD = least significant difference; CV = coefficient of variation. Means sharing the same letter(s) in each column do not differ significantly at 5% P level according to the LSD test.

4.4. Proximate Nutrient and Mineral Compositions of Castor Leaves relationship with Eri-silkworm traits

The foliar proximate composition of castor accession resulted in significantly different relationship with performance of eri-silkworms. The result of the relationship between leaf nutrient as well as mineral composition and eri-silkworm traits were worked out using Pearson's correlation coefficient analysis and the results are discussed below.

4.4.1. Moisture content and silkworm traits

Moisture content of leaves showed significant positive correlation with matured larval weight ($r=0.41960^{**}$) and hatchability ($r=0.2451^{*}$). In addition, non-significant positive correlation was observed with fecundity (r=0.10086), larva duration (r=0.045827), cocoon weight (r=0.096207), shell weight (r=0.029131) and ERR(r= 0.214136). Many scientists reported favorable effects of high moisture content of leaves on their palatability and digestibility by silkworm. Rahmathulla *et al.* (2006) observed positive relationship of mulberry leaf moisture content with matured larval weight, cocoon weight and shell weight but negative with larval duration. Also Kedir (2016) observed positive correlation of castor leaf moisture content with all silkworm traits. In addition, Ahmed (2015) observed a positive relationship of moisture content with silkworm traits and he found out feeding of wet leaf reduce larval duration while increasing all larval, cocoon and silk traits.

Furthermore, Talebi *et al.* (2002) observed that the cocoon weight, shell weight, pupa weight and eggs productivity increased with increasing leaf moisture content. Also Paul *et al.* (1992) observed in their studies that availability of moisture content in the leaves enhances the feeding efficiency of the larvae which in turn increases the growth rate.

Assimilated food conversion into body tissue and conversion efficiency decreased with decreasing dietary moisture content in leaves and also shell weight and fibroin content of the cocoons increased with increasing dietary moisture (Narayanaprakash *et al.*,1985). Availability of moisture content in the leaves enhances the feeding efficiency of the larvae, which in turn increases the growth rate (Singh *et al*., 2004). Moisture content of leaves plays a

very important role in silkworm metabolism as it regulates the rate of ingestion and determines the digestibility of feed by silkworms (Hazarika *et al*., 2005). Silkworm fed on leaf with higher moisture content (75%) produced heaviest cocoon. Leaf moisture content positively influenced silkworm larval growth and development (Singh *et al.*, 2004).

4.4.2. Ash content and silkworms traits

Ash content showed strong negative correlation with shell weight (r= -0.46787), shell ratio (r= -0.48676) and fecundity (r=-0.44694) and positive relation with larval duration (r= 0.08773). However, statistically non-significant but negative correlations were observed for the rest of the silkworm traits. Ash is responsible for maintaining physiological alkalinity of feed and plays an important role in digestion process of silkworms (Goel and Krishan, 2004). Reduction in ash content had been established as an advantage for better silkworm crop yield (Vasuki and Basavanna, 1969).

4.4.3. Crude fiber and silkworms traits

Crude fiber analysis in relation to the eri-silkworms traits revealed significant negative correlation with fecundity (r= -0.428), cocoon weight (r= -0.25006), shell weight (r=-0.402977) and shell ratio (r=-0.43388) but hatchability and ERR show non-significant negative correlation. It also show non-significant positive correlation with larva duration (r=0.25586), matured larval weight (r=0.027851). Crude fiber is indigestible part of foods. Therefore, it is required in lesser amount as they interfere with digestibility of the feeds (Maynard and Loosli, 1962). Reduction in fiber content had been established as an advantage for better silkworm crop yield (Vasuki and Basavanna, 1969).

4.4.4. Crude fat and silkworms traits

Crude fat content of the leaf showed significant positive relation with cocoon traits such as cocoon weight ($r=0.26122^{*}$), shell weight ($r=0.40596^{***}$), shell ratio ($r=0.32921^{**}$) and ERR ($r=0.35281^{**}$). However, negative relation was observed with larval duration (r= -0.38229) and non-significant positive relation with the rest of eri-silkworm traits. The present finding is in agreement with the finding of Kedir (2016) who observed significant positive relation

between crude fat with all silkworms trait except silk ratio and larval duration. Also Sarmah *et al*. (2011) observed positive correlation of lipid with larval and cocoon weight.

Fats which are available in feeds are important sources of energy. 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).

4.4.5. Total carbohydrate and silkworms traits

Total carbohydrate showed significant positive relation with fecundity ($r=0.2584^{*}$) and hatchability ($r=0.31711^{**}$). Non-significant positive correlation was also observed with shell weight (r= 0.00015), shell ratio (r=0.02778), ERR (r=0.09616), larval duration (r=0.12864). Kedir (2016) observed significant positive correlation of carbohydrate with cocoon traits. However, Sarmah *et al*. (2011) observed negative correlation of total carbohydrate with cocoon weight, larval weight, shell weight, shell ratio and ERR. In silkworm growth and development the degree of increase of fat body glycogen and haemolymph trehalose is dependent on the content of carbohydrate in diet (Horie, 1978).

4.4.6. Crude protein and nitrogen content and silkworms traits

As nitrogen is the most distinguishing chemical element present in proteins, nitrogen and crude protein showed the same correlation with silk worm trait. In this experiment, nitrogen had strong significant positive correlation with shell weight ($r=0.49548^{***}$) and shell ratio ($r=0.49689^{***}$) fecundity ($r=0.34806^{**}$) and non-significant but positive correlation with larval weight (r=0.25164), hatchability (r=0.00612), cocoon weight(r=0.20214) and ERR (r=0.00387). However, it showed negative non-significant correlation with larval duration (r=-0.21356).

Like that of nitrogen protein also showed strong significant positive correlation with shell weight ($r=0.49259^{***}$) and shell ratio ($r=0.50042^{***}$), fecundity ($r=0.35831^{**}$) and non-significant but positive correlation with larval weight (r=0.07798), hatchability (r=0.01006),

cocoon weight(r=0.19625) and ERR (r=0.01092). However, it showed non-significant negative correlation with larval duration (r=-0.22619). Similarly, Chandrashekhar and Pallavi (2015) observed negative correlation of nitrogen with larval duration, pupal duration and cocoon ratio. In addition Kedir (2011) observed significant positive correlation of nitrogen and protein with all silkworm traits.

Nitrogen content in leaf is known to influence the quality of leaf especially its protein content apart from, its control of plant reproduction cycle (Shankar, 1997). The role of proteins and amino acids in silkworm nutrition has been emphasized by Takeuchi (1960). Nitrogen is the most distinguishing chemical element present in proteins which in turn are the most ubiquitous organic nitrogenous compound in food stuff and in all living cells. In fact they appear to be involved in practically all the structure and functions of all cells (Mallette *et al*., 1960).

Protein content in leaf is a major source for silkworm to synthesize the silk which consists of two proteins namely fibroin and sericin (Rangaswami *et al.,* 1976). Similarly, Bongale and Chaluvachari (1995) also opined that, protein content of mulberry leaves has a profound impact on larval growth particularly in silk gland development and cocoon characters of silkworm.

As nitrogen is an important limiting factor for phytophagous insects, reduction of nitrogen contents might have forceful effects on insect performances. Insects increased their consumption and assimilation rates when fed on nitrogen-poor foliages (Rao *et al.,* 2009). The weights of larvae and cocoons are significantly influenced by nitrogen and crude protein content of foliage and free amino acids (Sarmah *et al*., 2011). Nitrogen as protein and non-protein nitrogenous matter present in the food plant leaves are responsible for healthy growth of silkworm as silk substances consists of protein **(**Sarmah *et al*., 2013)

4.4.7. Phosphorus content and silkworm traits

Analysis of phosphorus content of castor accession in relation to silkworm traits revealed significant positive relation with cocoon weight (r=0.15165), shell weight (r=0.0.34942**), shell ratio(r=0.0.32126**) and ERR (r=0.31042**), fecundity (r=0.26314*), matured larval weight (r=0.26974*) and hatchability (r=0.25138*). However, larval duration and survival rate showed non-significant negative relation with leaf phosphorus nutrient content (Table 9). Sarmah *et al*. (2013) observed significant positive relation between phosphorus and cocoon trait in India. Furthermore, Chandrashekhar and Pallavi (2015) observed negative correlation of phosphorus with larval duration, pupal duration and cocoon ratio while other characteristics have positive relationship.

Phosphorus is known to improve the total sugar content of leaf (Ray *et al.,* 1973). Thus, phosphorus in the leaf of feed plant affects larval duration, cocoon characters and silk quality of silkworms (Radha *et al.,* 1988; Shankar, 1990).

Table 9. Correlation coefficients between eri-silkworm traits and biochemical constituents of castor leaf

Silkworm traits	Leaf biochemical composition							
	Nitrogen	Protein	Ash	Fiber	Moisture	Phosphorus	Fat	Total carbohydrate
LD	-0.21356	-0.22619	0.08773	0.25586*	0.0458	-0.24088	-0.38229	0.12864
MLW	0.08233	0.07798	-0.03939	-0.02785	0.41960**	0.26974*	0.19008	-0.15106
FUC	0.34806**	0.35831**	-0.44694	-0.42800	0.10086	0.26314*	0.19005	0.25849*
HAT	0.00612	0.01006	-0.07709	-0.27975	0.24510*	0.25138*	0.18147	0.31711**
SRv	0.04214	0.03892	-0.03906	0.03806	0.02669	0.03415	0.03124	-0.09434
CW	0.20214	0.19625	-0.13017	-0.25006	0.17039	0.15165	0.26122*	-0.0418
SW	0.49548***	0.49259***	-0.46787	-0.40297	0.02913	0.34942**	0.40596***	0.00015
SR	0.49689***	0.50042***	-0.48676	-0.43388	-0.09888	0.32126**	0.32921**	0.02778
ERR	0.00387	0.01092	-0.05108	-0.10789	0.21414	0.31042**	0.35281**	0.09616

Where: LD=larval duration, MLW=matured larval weight, FUC =fecundity, HAT= hatchability, SRv= survival rate, CW= cocoon weight, SW=shell weight, SR=shell ratio, ERR=effective rate of rearing

Where *, **, *** denoting significant at ($P \leq 0.05$), ($P \leq 0.01$), and ($P \leq 0.001$), respectively

5. SUMMARY, CONCLUSIONS AND RECOMENDATION

Leaf quality is the major factor that influences the growth and development of silkworms as well as the production of quality cocoon. The rearers of eri-silkworm largely depends upon the use of castor leaves in conducting rearing as it produces the best result in respect of qualitative and quantitative characters of the eri-silk. In view of this, thirty two castor accessions were evaluated during the 2015/2016 academic year to examine agronomic performance, biochemical composition of castor leaves as well as rearing performance of eri-silkworm. Accordingly, the results of analysis of variance revealed significant differences in agronomic performance, biochemical composition and rearing performance of silk worms.

The present finding revealed that in the field condition, different castor accessions showed significant variation in agronomic performances. As a result, selection based on leaf biomass to use for eri-silkworm rearing revealed that Acc219668, Acc 200361 and Acc219662/1 were better than other accessions including local check. Furthermore, the biochemical composition of leaves has also revealed significant differences among castor accessions. Acc219662/1 was good in nitrogen and protein content while Acc 200361 was superior in phosphorus, fat and moisture content of the leaves. On the other hand, analysis of rearing performance of eri-silkworms while feeding different castor accession revealed that Acc 200361 was the most promising castor accession in respect to rearing performance of eri-silkworm.

Moreover, the relationship of biochemical constituents of castor accessions with cocoon characteristics showed a significant positive correlation with nitrogen, crude protein, crude fat, phosphorus, and moisture contents. Further, their interaction with larval traits found to have positive relationship with nitrogen, crude protein, crude fat, phosphorus, and moisture contents except larval duration. On the other hand, total carbohydrate showed negative relation with matured larval weight and cocoon weight of silkworm. In addition, larval duration showed positive correlation with ash and crude fiber content of the leaves while all other silkworm traits showed negative correlation with ash and fiber content.

Generally the present study revealed that castor accessions have strong influence on eri-silkworm rearing performance. Selection of castor accession is very much important to get better larval development, Cocoon and silk yield.

In conclusion from the study, Acc 200361 was found to be better performing accession in terms of agronomic performance together with rearing performances of eri-silkworm. Based up on the above conclusions, the following recommendations can be forwarded.

As a result of field and laboratory studies, Acc 200361 can be recommended for eri-silkworm rearing and sericulture development activities for the future. However, Acc219662/1 which is good in it biochemical composition will be considered as an alternative where brown leaf spot (*Cercospora ricinella)* disease problems are low or with availability of appropriate brown leaf spot disease management options.

Future studies should be conducted on these accessions to see their seed yielding performance and oil quality in relation to silkworm rearing. In addition, Acc 219668 due to its high fresh leaf yield it can be considered for future breeding work to increase fresh leaf yield of a given accession in combination with other agronomic performance. Further studies should continue giving more emphasis to multi-location evaluation of this castor accessions to understand how they react to diverse growing environment.

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7. APPENDICES

Appendeix1: Analysis of variance for agronomic parameters of castor accessions.

Source of variation	Df	Mean Square of agronomic parameter								
		DoE	NB	BL	PH	INL	LA	FLY	DS	DI
Block	1	2.640625	16.107680	1002.1181	9567.28516	4.1259766	196373.6	24433.6	51.986243	26.48389
Treat	31	1.1527217	3.6746549	1499.8739	2976.4031	27.804908	11141696	9344087.3	174.586243	329.32877
Error	31	0.4470766	0.9659588	798.64841	1273.8537	14.061460	66805.0	28207.4	25.789916	27.82959
CV (%)		6.018681	19.39556	17.85761	17.24272	18.4854	3.388224	1.561020	18.90926	18.60608
LSD(5%)		1.3637	2.0045	57.637	72.792	7.5808	527.15	342.54	10.357	10.759
F value		2.58	3.8	1.88	2.34	1.98	166.78	331.26	6.77	11.83
Pr >F		0.0051	0.0002	0.0421	0.0104	0.0311	<.0001	<.0001	<.0001	<.0001

Where: DoE: days of emergence, NB: number of primary branch, BL: branch length, PH: plant height, INL: inter-node length, LA: leaf area, FLY: fresh leaf yield, DS: disease severity, DI: disease incidence

Appendix 2: Analysis of variance for Biochemical composition of different castor accessions.

Source of variation	Df	Mean Square of Biochemical composition							
		MC	Nitrogen	Phosphorous	Protein	Fiber	Ash	Fat	Carbohydrate
Block	1	7.2697641	0.00384400	0.00280900	0.38579646	5.2635831	11.5192360	0.00023256	29.6875144
Treat	31	14.151677	1.16473634	0.2165423	46.017964	9.8922495	19.0825228	0.09950293	9.6618225
Error	31	5.2008221	0.07226284	0.01723390	2.854223	0.6596611	1.5748286	0.00809576	4.1358425
CV (%)		2.907062	10.79656	11.58995	10.83237	4.196260	6.881763	15.06039	4.404775
LSD (5%)		4.6512	0.5483	0.2677	3.4456	1.6565	2.5594	0.1835	4.1477
F value		2.72	16.12	12.56	16.12	15.00	12.12	12.29	2.34
Pr >F		0.0034	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0105

Where: MC: moisture content

Appendix 3 Table 1: Analysis of variance for rearing performance of eri-silkworms in the first rearing

Source of variation	Df	Mean Square of rearing performance of eri silkworms								
		Fuc	HAT	LD	MLW	SRv	CW	SHW	SR	ERR
Rep	1	0.7877	2.1389062	0.140625	0.0014063	0.0156250	0.0014063	0.0000014	0.034225	45.22563
Treat	31	8044.195	8.3605192	2.1849798	0.5076563	0.1325605	0.0905192	0.0045546	1.228653	40.76917
Error	31	105.7923	1.2308417	0.1083669	0.0349546	0.8014113	0.0188256	0.0008665	0.512669	13.34175
CV (%)		0.867365	1.174217	1.697683	2.785924	0.288639	4.015186	5.801148	4.813193	3.894718
LSD(5%)		3.7677	2.2627	0.6714	0.3813	0.5774	0.2798	0.06	1.4603	7.4496
F value		2357.17	6.79	20.16	14.52	1.65	4.81	5.25	2.40	3.06
Pr >F		<0001	<.0001	<.0001	<.0001	0.0834	<.0001	<.0001	0.0087	0.0013

Where: fuc: fecundity, HAT: hatchability, LD: larval duration, MLW: matured larval weight, SRv: survival rate, CW: cocoon weight, SW: shell weight, SR: shell ratio, ERR: effective rate of rearing

Appendix 3 Table 2: Analysis of variance for rearing performance of eri-silkworms in the second rearing

Source of variation	Df	Mean Square of rearing performance of eri silkworms								
		Fuc	HAT	LD	MLW	SRv	CW	SHW	SR	ERR
Rep	1	39.8477	2.138906	0.015625	0.0076562	0.0000	0.01	0.0011475	0.8212891	45.22563
Treat	31	7145.51	8.360519	1.9430444	0.5354788	0.564516	0.0818545	0.0012115	0.8341149	40.76917
Error	31	211.892	1.230842	0.1446573	0.0186240	0.403226	0.2419355	0.0005836	0.4438278	13.33540
CV (%)		7.10566	1.174217	1.868124	2.887294	0.204122	6.971104	9.149737	5.637063	3.894718
LSD (5%)		3.37677	29.688	0.6714	0.3813	0.4095	0.2798	0.06	1.4603	7.4496
F value		33.72	6.79	13.43	28.75	1.40	3.38	3.1	1.88	3.06
Pr >F		<0001	<.0001	<.0001	<.0001	0.1770	<.0001	0.0011	0.0420	0.0013

Where: fuc= fecundity, HAT= hatchability, LD= larval duration, MLW= matured larval weight, SRv= survival rate, CW= cocoon weight, SW= shell weight, SR= shell ratio, ERR= effective rate of rearing

Appendix 4. Figures showing field and laboratory observation

Fig .1. Castor plants in the field

Fig. 2. Castor leaf affected by brown leaf spot (*Cercospora ricinella*)

Fig. 3. Eggs of eri-silkworm

Fig. 4. Hatched first instar larva

Fig. 5. Third instar larva

Fig. 6. Fourth instar larva

Fig. 7. Matured fifth instar larva

Fig. 8.Cocoon of eri-silkworm

Fig. 9. Tray arrangement for rearing of eri-silkworm in the laboratory