ijiar ISSN 2348 - 0319

Journal home page: http://www.journalijiar.com

INTERNATIONAL JOURNAL OF INNOVATIVE AND APPLIED RESEARCH

RESEARCH ARTICLE

Feed Utilization Efficiency of Eri-Silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) on Eight Castor (*Ricinus communis* L.) Genotypes

[1]Kedir Shifa, [2]Waktole Sori and [3]Emana Getu

[1]Melkassa Agricultural Research Center, P.O.Box 436, Nazareth, Ethiopia.

[2]Jimma University, P.O.Box 307, Jimma, Ethiopia.

[3]Addis Ababa University, P.O.Box 1176, Addis Ababa, Ethiopia.

Abstract:

Eri silk production and productivity depends highly on feeds consumed by eri silkworms (*Samia cynthia ricini* B.), which will be a function of feed sources. Preferred feed of eri silkworms is castor, however, there is an important difference in feed utilization efficiency when different castor genotypes were used as feed source for this silkworm. In this experiment, feed utilization efficiency of eri silkworm was studied on eight different castor genotypes namely Abaro, Acc 106584, Acc 203241, Acc 208624, Ar sel, Bako, Hiruy and local genotypes in Melkassa Agricultural Research Center, Ethiopia. The treatments were laid out in a Completely Randomized Design (CRD) in three replications. Fifty worms after their fourth molt were placed on rearing trays provided with castor leaves harvested from the eight different genotypes. The genotypes caused significantly different feed utilization efficiency on eri silkworm. Among castor genotypes, Abaro and Acc 208624 expressed better performance in all evaluated variables simultaneously. These genotypes yielded 6.672 and 6.904 g/larva of ingesta, 3.379 and 3.574 g/larva of digesta, 50.637 and 51.766 % approximate digestibility, 2.026 and 2.073 reference ratio, 0.814 and 0.862 relative consumption rate, 33.164 and 31.406 % efficiency to convert ingested leaves to larval biomass, 19.811 and 19.236 % efficiency to convert ingested food to cocoon as well as 39.126 and 37.173 % efficiency to convert digested food to cocoon, respectively. As a result, these castor genotypes were recommended to future research and development endeavors of integrated eri silkworm farming and castor seed production.

Key Words: Castor genotypes, eri silkworm, integrated production, *Samia cynthia ricini*, feed utilization efficiency

Introduction

Silk is a natural protein fiber secreted by arthropods especially lepidopteran silkworms (Chowdhary, 2006). It is very soft, lustrous, smooth, strong and durable than any natural or artificial fibre. The industrial and commercial uses of silk contributed to the silkworm promotion all over the world especially in developing nations. This opens ways for integrating agricultural practices with silk production as with animal husbandry, dairying, fisheries and horticulture, which will improve the overall productivity of the societies (Sahay *et al*., 1997; Lamelu, 1998; Hiwar, 2001 and Tzenov, 2007).

In Ethiopia, rearing of eri and mulberry silkworm is practiced sparsely. However, eri silkworm rearing for eri silk production is better practiced compared to the mulberry one. Here, the availability of adequate labor, suitability of soil and climatic conditions for host plant cultivation as well as eri-silkworm rearing are among the factors contributed to progresses in eri-culture (Metaferia *et al*., 2007).

The eri silkworm, *Samia cynthia ricini* Boisduval, which belong to family saturnidae, is the one among the commercially exploited sericigenous insects (Joshi, 1992). It is a multivoltine and polyphagous species and it can be reared throughout the year depending on the availability of feed (Thangavelu and Phukon, 1983 and Debaraj *et al*., 2003). Castor (*Ricinus communis* L.) is the primary food plant for this insect compared to other host plants (Devaiah *et al*., 1985).

In general, the quality of feeds given to insects generally affects the economic products of insects. So, silkworm nutrition is the major factor which affects development and productivity of silkworms (Solanki and Joshi, 2001). Silkworms feed to derive and store adequate energy, nutrients and water from the food they consume

(Krishnaswami, 1978). Thus, the quality of leaves fed to the larvae of eri-silkworm does have a bearing effect on the quantity and quality of the cocoons produced. The better the quality of leaves, the greater will be cocoon production and productivity (Sannappa and Jayaramaiah, 1999). Therefore, the properties of the feeds including their morphological features, susceptibility to enzymatic hydrolysis, the action of inhibitory substances like glucosides, tannins, alkaloids, etc., and the total processing capacity of the insects digestive system will determine the value of the feed. As a result, chemical composition and digestibility of the feeds have significant importance. However, one feed type may be more valuable than the other because its digested matter can be used to better advantage by the insects (Maynard and Loosli, 1962).

Therefore, the suitability of feed can be determined through estimation of rate of ingestion, digestibility, conversion efficiency of food and growth rate of the insect. So, the quantitative nutritional approach consists of measuring the amount of food consumed, digested and assimilated, excreted, metabolized, and converted into biomass is of high importaance together with qualitative approaches (Maynard and Loosli, 1962; Ramesh *et al*., 2010. In addition, identifying the factors that contribute more to how organisms respond to different foods and food components is highly essential (Sannappa and Jayaramaiah, 1999).

As a result, selection of castor genotypes for their suitability to eri silkworms based on the silkworms feed utilization efficiency is highly required (Joshi and Misra, 1982). However, very little information is available in Ethiopia. This work, therefore, attempts to assess the influence of castor genotypes on feeding efficiency of eri silkworm, *S. c. ricini* and to find out promising castor genotype (s) for better eri silk productivity.

Materials and Methods

Description of the study area

The study was conducted at Melkassa Agricultural Research Center (MARC), Ethiopia, located at 8°24'N latitude and 39°12'E longitude. It has an elevation of 1500 meters above sea level and a mean annual rainfall of 770 mm.

Experimental setup

As per the rearing recommendations of silkworms by Dayashankar (1982), a white plain eri-silkworm breed was used for this experiment and it was reared on the eight castor genotypes namely Abaro, Acc 106584, Acc 203241, Acc 208624, Ar sel, Bako, Hiruy and local check. The silkworm rearing room and equipments were cleaned, washed and disinfected with 2% formalin solution at the rate of 800ml per $10m^2$ before the commencement of the experiment. This breed was reared following cellular rearing techniques starting from brushing till cocoon spinning on the eight genotypes. Tender leaves of castor were fed four times a day until the larvae ends II instar stage, and semi tender leaves to III instar while more matured leaves were fed to IV and V instar larvae. The laboratory experiment was arranged in Completely Randomized Design (CRD) in three replications. For each treatment, 50 worms after their fourth molt were used and allowed to complete the larval and pupal periods.

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

As used by Neupane *et al*. (1990), matured worms were picked and mounted on the mountages for spinning. On the six day of spinning, the cocoons were harvested, counted and weighed. The following formulae, which were used by Ramesh *et al*., 2010 adopted for feeding efficiency analysis:-

Ingesta = Dry weight of leaf fed - Dry weight of left over leaf
Digesta=Dry weight of leaf ingested - Dry weight of litter
Excreta=Ingesta - Digesta
Mean larval weight= (Final weight - Initial weight)/2 + Initial weight
AD (%)= Dry weight of Digesta x 100/Dry weight of food ingested
RR (%) = Dry weight of food ingested x 100/Dry weight of excreta
RCI = Ingesta/(Mean Dry weight of larva x Larval duration in days)
RGR = Dry weight gain of the larva/(Larval duration in days x Mean dry weight of the larva)
ECI to larva= Maximum dry weight of larva x 100/Dry weight of ingesta
ECD to larva= Maximum dry weight of larva x 100/Dry weight of digesta
ECI to cocoon= Dry weight of cocoon x 100/Dry weight of ingesta
ECD to larva= Maximum dry weight of larva x 100/Dry weight of digesta
ECI to shell= Dry weight of shell x 100/Dry weight of ingesta
ECD to Shell = Dry weight of shell x 100/Dry weight of digesta

Data Analysis

Finally, the data were analyzed statistically by using SAS software at 5% level of significance. LSD was used as mean separation tool (SAS Institute Inc, 1999-2000).

Results

The eight castor genotypes caused significant variation in different consumption indices when served as feed source for eri silkworms.

Total food consumption (Ingesta)

Silkworms consumed significantly higher leaf when reared on leaves of Hiruy (7.142 g/larva). Further, local check (7.087 g/larva), Acc 208624 *(*6.904 g/larva), Acc 106584 (6.676 g/larva) and Abaro (6.672 g/larva) genotypes found next best with regard to food consumption. The same was very lower with Bako (5.925 g/larva) (Table 1).

Total food digestion (digesta)

Food digested by the eri silkworm was found to vary significantly among the castor genotypes used. Food digestion was more with local leaves (6.661 g/larva) and was closely followed by Acc 106584 (3.589 g/larva) and Acc 208624 (3.574 g/larva). However, the worms fed on leaves of bako genotype recorded lower food digestion (2.598 g/larva) (Table 1).

Excreta

Food excreted by the eri silkworm was found significant among the castor genotypes used. It was more with Hiruy leaves (3.713 g/larvae) and was found followed by Acc 203241 (3.440 g/larva) and local genotype (3.427 g/larva). However, the worms fed on leaves of Acc 106584 genotype showed lower excreta (3.087 g). (Table 1)

Table 1: Effect of castor genotypes on the amount of eri silkworm ingestion, digestion and excretion

Castor genotypes	**Ingesta**	**Digesta**	**Excreta**
Abaro	6.6717^{abc}	3.3783^{abc}	3.29333^{c}
Acc106584	6.6760^{abc}	3.5893^{ab}	3.08667^{d}
Acc203241	6.6170^{bc}	3.1770^{bc}	3.44000^{b}
Acc208624	6.9043^{ab}	3.5743^{ab}	3.33000^{bc}
Ar sel	6.3707^{cd}	3.0640^{c}	3.30667^{c}
Bako	5.9250^{d}	2.5983^{d}	3.32667^{bc}
Hiruy	7.1423^{a}	3.4290^{abc}	3.71333^{a}
Local	7.0873^{ab}	3.6607^{a}	3.42667^{b}

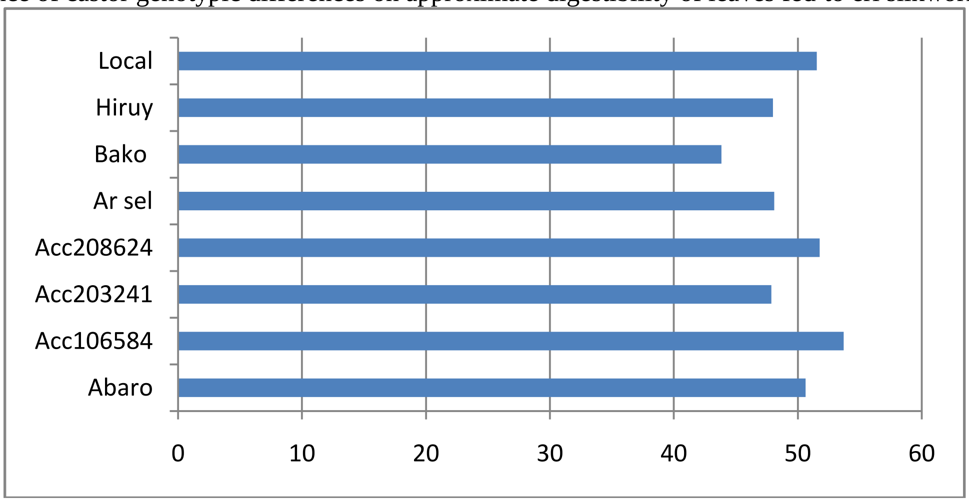
SE	0.1711	0.1532	0.0395
CV	4.4411	8.0188	2.0344
Pr	0.0026	0.0027	<.0001

* Means followed by the same letter with in a column are not significantly different from each other at 5% level of significance

Approximate Digestibility (AD)

Significant differences were noticed with respect to AD when leaves of different castor varieties fed to eri silkworms indicating that higher food intake does not necessarily result in higher digestibility. Significantly higher AD was recorded in Acc 106584 (53.704 %) along with Acc 208624 (51.766 %) and local (51.535 %) and Abaro (50.637 %). However, worms fed on Bako showed lower AD (43.840 %) (Fig. 1).

Fig.1: Influence of castor genotypic differences on approximate digestibility of leaves fed to eri silkworm



Reference Ratio (RR)

Reference Ratio (RR) which is indicative of the retention efficiency of food as stated by Rahmathulla *et al*. (2003) was significantly higher with Acc 106584 (2.161), Acc 208624 (2.073), local (2.069) and Abaro (2.026) genotype fed worms. The least RR was noticed from Bako (1.781) (Fig. 2).

Relative Consumption Index (RCI)

Significantly higher RCI was noticed from Acc 106584 (0.932) and local (0.901) fed worms, but lower RCI was noticed with Ar sel (0.745). So, the local genotype was better than all in this regard except Acc 106584 (Fig. 2).

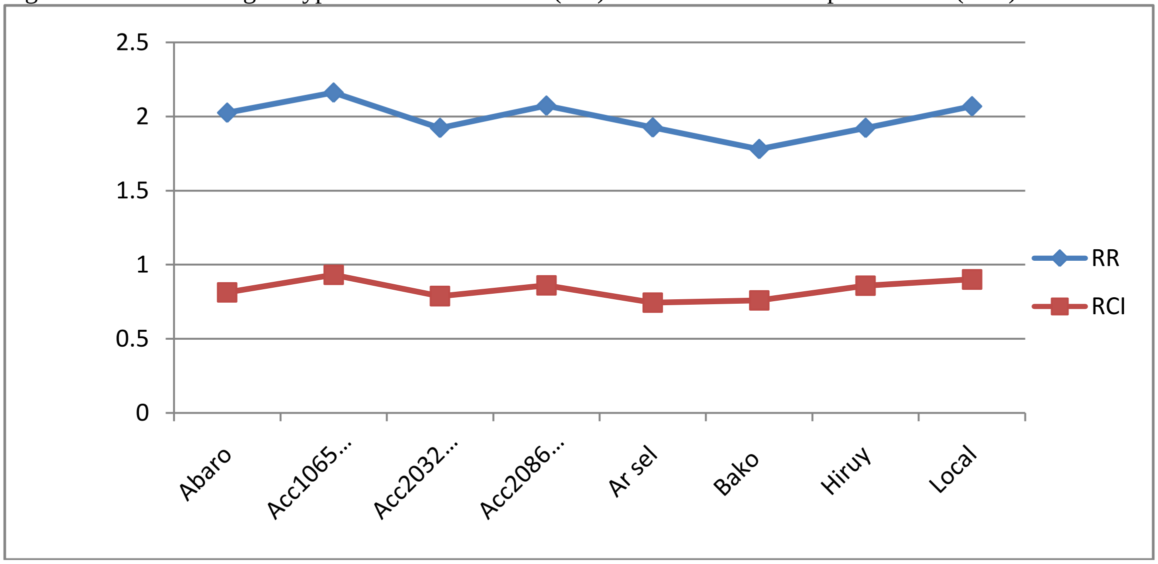
Relative Growth Rate (RGR)

There was no significant statistical difference with regard to RGR among the worms fed with different castor genotypes though mean variations were obvious. Mean RGR was higher with local (0.260) and lesser with Ar sel (0.231).

Efficiency of conversion of Ingesta to larval biomass (ECI to larva)

The efficiency of ingested leaf conversion into silkworm larval biomass varied significantly among castor genotypes. The highest efficiency of conversion of ingesta (ECI) to larva was recorded from Bako (35.191 %) and least in Acc 106584 (28.950 %). The local check recorded 30.386 % and was the least except Acc 106584 (Table 2).

Fig.2: Effect of castor genotypes on reference ratio (RR) and relative consumption index (RCI) of eri silkworm



Efficiency of conversion of digesta to larval biomass (ECD to larva)

Efficiency of Conversion of Digesta (ECD) to larval biomass has revealed no statistical significant variation among the castor genotypes. However, mean values show that more efficient conversion of digested food into larval biomass was recorded in Ar sel (75.953%) and less efficient conversion was recorded in local genotype (55.638 %) (Table 2).

Efficiency of conversion of Ingesta to cocoon (ECI to cocoon)

Efficiency of Conversion of Ingesta (ECI) to cocoon revealed significant difference and it was higher in Abaro (19.81 %) followed by Acc 208624 (19.24 %) and Bako (18.897 %). It was lower in Hiruy (15.83 %) and local genotype (16.06 %) (Table 2)

Efficiency of conversion of Ingesta to cocoon (ECD to cocoon)

Efficiency conversion of digesta (ECD) to cocoon varied significantly among the castor genotypes which ranged between 31.30 % (local) to 43.136 % (Bako). The more efficient genotype was Bako. The second best genotypes were Abaro (39.126%) and Acc 208624 (37.173 %) (Table 2).

Table 2: Influence of castor genotypes on efficiency of conversion of ingesta and digesta to larval biomass and cocoon by eri silkworm

Castor genotypes	ECI to larva	ECD to larva	ECI to cocoon	ECD to cocoon
Abaro	33.164[abc]	63.189[abc]	19.8110[a]	39.126[ab]
Acc106584	28.950[d]	58.194[bc]	17.1543[bc]	31.989[de]
Acc203241	33.898[ab]	67.837[abc]	16.7040[bc]	35.109[bcde]
Acc208624	31.406[bdc]	64.649[abc]	19.2360[a]	37.173[bc]
Ar sel	34.728[a]	75.953[a]	17.5507[b]	36.493[bcd]

Bako	35.191[a]	72.213[ab]	18.8970[a]	43.136[a]
Hiruy	31.273[bcd]	65.898[abc]	15.8333[c]	33.032[cde]
Local	30.386[cd]	55.638[c]	16.0640[c]	31.30[e]
SE	0.9941	4.8026	0.4423	1.5229
CV	5.3182	12.7102	4.339	7.3434
Pr	0.0039	0.1253	<.0001	0.0008

* Means followed by the same letter with in a column are not significantly different from each other at 5% level of significance

Discussion

As it can be understood from the results, castor genotypes (Abaro, Acc 106584, Acc 203241, Acc 208624, Ar sel, Bako, Hiruy and local check) showed wide variation in feeding efficiency of eri silkworms when leaves of these genotypes were used as a feed source. Analysis of feeding efficiency of eri silkworms fed on castor genotypes was carried out by using the 5th instar larva. This is because 97 % of the total food intake in silkworms is made during the last two instars. During 5th instar, however, 80-85 % of the total leaves are consumed and silkworms are very active metabolically at this stage (Rahmathulla *et al.*, 2005). Hence, the present analysis in regard to feeding efficiency of eri silkworms was confined to 5th instar and it has revealed significant differences.

Among castor genotypes studied, Abaro revealed consistently highest efficiency of ingesta to cocoon, ingesta to larva, digesta to cocoon and approximate digestibility. Furthermore, Acc 208624 revealed higher ingesta, digesta, approximate digestibility, reference ratio and consumption index as well as efficiency of ingesta to cocoon when fed to eri silkworms. On the other hand, local genotype showed lower conversion efficiency to larval biomass and cocoon weight though it was good enough in other parameters. These difference were because of the quality of leaf fed has a great influence on the amount ingested food due to the physico-chemical characteristics in relation to the age of the leaf and the characteristics of the genotypes as stated by Legay (1958) and Friend (1958).

In case of castor genotypes, Ar sel and Bako ingesta and digesta fluctuated at around or below medium, but their conversion to larval biomass and cocoon were relatively good enough. It could happen because low food intake may be offset by a high utilization of ingested or digested food. Conversely, high food intake from Acc 106584, Hiruy and local genotype revealed that it may not necessarily lead to efficiency in the utilization of food being attributable to leaf nutrient composition. This will also be justified by the fact that the conversion efficiency of food-ingested and digested are somewhat dependent on digestibility, leaf moisture content and presence of optimum mineral nutrients as explained by Scriber and Slansky (1981) and Slansky and Scriber (1985).

Therefore, this study revealed that overall Abaro and Acc 208624 provided significantly higher feeding and conversion efficiency to eri silkworms. Similarly, the findings of Basaiah (1988) and Reddy and Swamy (1999) in India showed same trend as above with regard to feeding efficiency when eri worms were fed on different castor varieties. These differences could also be attributable to the overall variation in the quality of castor leaves as reported by Legay (1958). Further, the report of Govindan *et al* (2003) who recorded 26.38 % - 28.35 % of conversion of ingested food to cocoon and 38.37 % - 40.26 % conversion of digested food to cocoon can be comparable with the records obtained from the present study that showed 15.83 %- 19.81% and 31.3 - 43.14% conversion of ingested food to cocoon and conversion of digested food to cocoon respectively from different castor varieties.

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

Conclusion and Recommendations

The present experiment indicated that selection and/or evaluation of castor genotypes based up on feed utilization efficiency of eri silkworms is very essential to achieve better eri silk productivity. Final analysis of feed utilization efficiency of eri silkworms from different castor genotypes revealed that genotypes Abaro and Acc 208624 as superior genotypes compared to others. As a result, these genotypes will be recommended for eri silkworm research and development works in the future.

However, additional research should be carried out to study the biochemical composition of leaves of these castor genotypes and to identify their interrelationship with silkworms larval and cocoon traits. In addition, more research should also be carried out to support the current findings in consideration with leaf productivity studies under field condition and on the possibilities of optimized integration of eri silkworm rearing with castor oil seed production.

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