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Research Article

Evaluation of Castor (*Ricinus communis* L.) Genotypes and Their Feeding Values on Rearing Performance of Eri Silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) in Southwest Ethiopia

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The quality of feed plays an important role in the growth and development of silkworms and eventually in the economic traits of cocoons. This study was conducted to evaluate ten castors (*Ricinus communis* L.) genotypes and their feeding values on the rearing performance of Eri Silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae) at Tepi, southwest Ethiopia. A total of ten castor genotypes were evaluated in a randomized complete block design (RCBD), and the suitability of castor genotypes as feed for a mixed strain of Eri-silkworm was also evaluated in a completely randomized design (CRD) under laboratory conditions. A hundred worms were used in each replication. Castor genotypes showed significant differences in fresh leaf yield. Among the castor genotypes tested, genotype 219645 recorded 439 g of ten fresh leaf yields. Results of Eri-silkworm rearing performance depict that a shorter larval period (22 days), a higher effective rate of rearing (94.54%), and a shorter life cycle (58 days) were observed in Eri-silkworm fed on leaves of the 200390 genotype, while a higher larval weight (6.16 g) was recorded in the Abaro genotype. However, higher cocoon weight (3.26 g), pupal weight (2.46 g), shell weight (0.45 g), and silk ratio (13.80%) were found in Eri-silkworms fed on leaves of genotype 219645. Hence, based on silkworm rearing performance, genotype 219645 showed relatively superior results and is recommended for future development work. Further studies should continue giving more emphasis to the multilocation study of genotype 219645 to understand its performance in the diverse growing environment.

1. Introduction

Silk production is the process of obtaining natural silk fiber through silkworms. Silk production can be practiced in varying agro-climatic conditions and it is suited to different production systems [1]. The practice of silk production involves diverse activities from the cultivation of host plants to silk processing, which engages people of all spectrums. Furthermore, the by-products also have various uses ranging from fertilizers in rural areas to pharmaceutical industries which could be tapped to increase the income of farmers and other societal groups in the long term [2]. Silk production has the potential to make a significant contribution to the economy of many countries where there is surplus labor, low costs of production, and willingness to adopt new technologies [3, 4].

Silk had a strong affinity with the people of Ethiopia since the ancient period of the country's civilization. Nonetheless, the silk yarns used in the country were imported from India, Arabia, and China [5]. Currently, Ethiopia is the second most populous country in Africa. There is a general trend of increasing unemployment. Thus, sericulture, an agro-based labor-intensive, and environment-friendly cottage industry, can become an efficient and effective income-generating activity. Thus, it is important to introduce and strengthen the technology in Ethiopia to diversify exportable or import substitution items; reduce the migration of people from rural to urban areas, and incorporate byproducts into the plantation fields and in the feeds of animals like poultry and fish [6–8]. As a result, silk production from Eri silkworm is practiced in different parts of the country, especially by poor farmers as an additional income source through the efficient use of family labor [9].

Several studies have been carried out on silkworm breeding or sericulture worldwide over the centuries and it continues today. Researchers have been trying to establish a certain type of silkworm for low production costs of cocoons, adaptation to varying agro-climatic conditions, disease, pests, high-temperature resistance, polyphagy, and choice of quality silk. As a result, superior and hardy breeds have been produced through continuous breeding, which has shown a very significant variation in yield, quality, management, and need for the environment [10, 11].

Castor (*Ricinus communis*) is the major feed plant for Eri-silkworm (*Samia cynthia ricini* Boisduval) (Lepidoptera: Saturniidae). The Eri silkworm is a polyphagous insect, which feeds on the leaves of several plant species including castor (*R. communis*), *Heteropanax fragrans*, *Evodia flaxinifolia*, and *Manihot utilissima* [11, 12]. Nevertheless, castor is the main host plant of Eri-silkworm. Eri-silkworms reared on castor leaves yield large cocoons rich in silk content [11]. In the development of sericulture, the quality of feed plays a significant role in the growth of the silkworm and ultimately in the economic trait of cocoons [2, 11]. The rearing of Eri-silkworm largely depends on the use of castor leaves in conducting rearing as it produces the best result in terms of qualitative and quantitative characteristics of the Eri-silk [11].

The Eri-silkworm is one of the most exploited, domesticated, and commercialized nonmulberry silkworms. It has many generations per year and feeds on several host plant species [13, 14]. It is a domesticated silkworm and can be raised indoors. Among all the host plants, *R. communis*is is the most preferred host plant for Eri-silkworm [2]. Moreover, about 25–40% of castor foliage can be defoliated (removed) and used for feeding Eri-silkworms without affecting oilseed production [12]. As a result, the breeding of silkworms is one of the continuous activities of the silk-producing world.

The quality of leaves provided to the Eri-silkworm feeding has been considered as a principal factor influencing the production of a good cocoon [11, 15]. It has been observed that growth, development, and cocoon yield are influenced by the castor genotype and the quality of leaves fed to the worms [16]. Hence, it is important to get a high-yielding and good-quality castor genotype for rearing silkworms. This study was carried out to evaluate castor genotypes and their feeding values on the rearing performance of Eri-silkworms.

2. Methodology

2.1. Description of the Study Area. The experiment was conducted at Tepi Agricultural Research Center which is located in southwest Ethiopia, 610 kilometers far away from Addis Ababa, the capital city of the country. It has an altitude of 1200 m. a. s. l. With a minimum of 600 mm and a maximum of 1500 mm annual rainfall, and 20 to 28°C minimum and maximum annual temperature, respectively. The area has high humidity and is rich in fauna and flora biodiversity.

2.2. Experimental Materials and Design. A total of 34 castor genotypes were collected from different areas of the country and planted in the research center for screening purposes. Then, ten castor genotypes were selected from thirty-four genotypes based on their yield performance and used for this experiment. Furthermore, eggs of Eri-silkworm were brought from Melkassa Agricultural Research Center for evaluation of Eri-silkworm performance feeding on those castor genotypes. To evaluate the agronomic performance of ten castor genotypes, treatments were arranged in a randomized complete block design with three replications. A feeding experiment was conducted in the laboratory to identify the best castor genotypes as feed for Eri-silkworm. Treatments were arranged in a completely randomized design with three replications for each treatment. In each replication, 100 worms were used and allowed to complete the larval development period.

2.3. Experimental Procedures. The castor genotypes were sown at a spacing of 75 cm × 70 cm between row and plant, respectively. The plot size was kept constant at 2.8 × 3 m each, and each plot has four lines with 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 the net plot. Four sample plants from net plots were taken as a sampling point for data measurements. Blocks and plots were spaced at two meters and one meter, respectively. Castor genotypes were planted and managed similarly in every plot except for the differences in their genetic makeup. The first weeding was done 30 days after sowing and the second and third weeding were done 60 and 90 days after planting, respectively.

The silkworm rearing room and equipment were cleaned, washed, and disinfected with 2% formalin solution at a rate of 800 ml per 10 m^2 before the commencement of the experiment (rearing). The mixed strain of Eri-silkworm was used for this experiment. Upon hatching, young age instars (1^{st}–3^{rd}) were fed with young shoots chopped to the size appropriate for the growing larvae. Whereas late-age instars (4^{th}-5^{th}) were fed with medium to mature leaves. Young age larvae were fed with tender, succulent, and nutritious leaves which are known to favor the growth and development of silkworms, while mature and coarse leaves were fed to larvae when they grew to ripening. Normal daily feedings of four times per day were given to each silkworm race. Rearing beds were cleaned every day before the first feeding. The room temperature and relative humidity were maintained based on recommendations. Mount ages were arranged to be timely for matured worms. Cocoon yield was harvested after the seventh day of mounting.

Table 1: Agronomic performance of castor genotypes under Tepi conditions.

Castor genotypes	50% emergency date	Stand count	Plant height at three month	No. of leaves per plant	Primary number of branch	Internodes length	50% flowering date	Disease and pest incidence (%)
Tepi local	12.66[ab]	9.667	247.33[ab]	21.33[a]	19.33[a]	11.00[ab]	78.67[a]	13.30[a]
219671	13.33[ab]	9.000	232.67[ab]	23.33[a]	22.00[a]	9.00[ab]	91.67[a]	10.00[ab]
219682	15.33[ab]	7.000	232.97[ab]	25.67[a]	25.00[a]	11.33[a]	92.00[a]	10.0[ab]
219650	12.00[b]	9.667	277.23[a]	23.33[a]	21.33[a]	10.67[ab]	95.67[a]	13.3[a]
200390	16.33[a]	9.000	216.63b[c]	26.33[a]	21.33[a]	7.33[b]	93.00[a]	13.3[a]
Abaro	15.33[ab]	7.667	230.33[ab]	25.67[a]	24.00[a]	9.67[ab]	95.67[a]	0.00[b]
219645	12.67[ab]	9.667	178.90[c]	24.33[a]	24.00[a]	8.33[ab]	95.33[a]	10.00[ab]
106564	14.00[ab]	8.333	240.70[ab]	24.67[a]	23.67[a]	10.00[ab]	86.33[a]	6.70[ab]
212631	14.00[ab]	9.000	233.97[ab]	26.00[a]	24.33[a]	9.33[ab]	79.00[a]	13.30[a]
Wolenchite	14.67[ab]	6.333	233.33[ab]	22.67[a]	22.00[a]	10.33[ab]	83.33[a]	13.30[a]
P-value	0.010	0.610	0.030	0.069	0.025	0.028	0.308	0.210
CV (%)	1.85	4.787	1.08	3.18	2.36	2.82	1.35	5.19

The means within a column followed by different letters are significantly different at $P < 0.05$ (the Tukey test).

2.4. Data Collected. Agronomic data of castor genotypes, namely, plant height at three months, 50% emergency date, leaves per plant, primary number of branches, 50% flowering date, internode length, ten fresh leave weights (g), ten dry leave weights (g), leaf area (cm^2), seed yield/plant (g), disease and pest incidence, and number of racemes per plant were collected. Furthermore, all the necessary data on the rearing performance were collected during the study period, which include the number of larvae left after each molting stage under observation (at 1st–4th instars), the total number of larvae reaching full maturity, the weight of ten matured larvae (g) at 5th instar at 6 days of age, developmental period (egg, larvae, pupae, and adult longevity), date of mounting, date of harvesting, fresh weight of single cocoons (g), fresh weight of shells (g), silk shell to cocoon ratio (%), numbers of eggs/female adult moth (fecundity), the first date of hatching, and the last date of hatching.

The following formula, which was adopted by Singh and Benchamin [17] was used for data on rearing performance:

$$\begin{aligned}
&\text{Hatchability (\%)}\\
&\quad = \frac{\text{No.of normal eggs} - \text{No.of non} - \text{hatched eggs}}{\text{No.of normal eggs}} \times 100,\\
&\text{Silk ratio}\\
&\quad = \frac{\text{Weight of the cocoon shell}}{\text{weight of fresh cocoon}} \times 100,\\
&\text{The effective rate of rearing (ERR)}\\
&\quad = \frac{\text{No.of larvae spinning cocoon}}{\text{No.of larvae brushed}} \times 100.
\end{aligned} \tag{1}$$

2.5. Data Analysis. All the collected data were tested for homogeneity of variance and normality. Those data that were found to have normal distributions were subjected to analysis of variance using SAS 9.0 (SAS, 2008). The variation between treatment means was compared using the least significance difference (LSD) test at a 5% level of significance.

3. Results and Discussion

3.1. Field Performance Different Castor Genotypes. The current result showed that the day of 50% seedling emergence was significantly ($P < 0.05$) different among the tested genotypes. Genotype 219650 was an early emerging genotype, which took 12 days to emerge and much earlier than the check (Abaro). However, genotype 200390 took longer days (16.33) compared to the check (Table 1). This variation in emergence might be due to genotype differences and seed size. In earlier studies, Oplinger et al. [18] stated that castor seed takes 10 to 12 days to emerge, which is in line with the current result. This result also agrees with the findings of Ozturk et al. [19], and Williams and Swinbank [20], who reported that castor requires 10 to 21 days for seedling emergence based on soil moisture and castor varieties.

In the present study, significant differences were detected in plant heights and internode length of castor genotypes. Plant heights for the tested genotypes ranged from 1.78 m (genotype 219645) to 2.77 m (genotype 219650). In addition, internode length varied from 7.33 cm for genotype 200390 to 11.33 cm for genotype 219682. However, medium plant height (2.30 m) and internode length (9.67 cm) were recorded in the standard check (Abaro) genotype (Table 1). The variation recorded in this study may indicate the presence of heterogeneity among the castor genotypes for these agronomic characteristics. Similar to this study, the castor genotype Abaro registered an internode length of 9.29 cm while Bako registered a short internode (5.95 cm) [15]. In another study, the castor genotypes evaluated for Eri-silkworm rearing showed a significant difference in plant height and internode length among genotypes [21, 22]. The variation in terms of plant height and internode length may be due to the inherent difference between those castor genotypes. Plant height and length are controlled by the inherent genetic constitution of the plant [23].

The present results revealed that the leaf area was significantly affected by different castor genotypes. The value of the leaf area ranged from 1020 cm^2 (Tepi local genotype) to 1661.33 cm^2 (200390 genotypes) as stated in Table 2. This may be due to the inherent variability that exists within the

Table 2: Agronomic performance of castor genotypes under Tepi conditions.

Castor genotypes	Ten fresh leave weight (g)	Ten dry leave weight (g)	Number of raceme per plant	Seed yield/plant (g)	Steam thickness	Leave area (cm^2)
Tepi local	258.33^{c}	108.33	1.667	8.00	9.67	1020.00^{b}
219671	302.00^{abc}	125.68	1.333	8.33	9.33	1155.00^{ab}
219682	334.67^{abc}	105.00	2.000	5.68	8.67	1186.64^{ab}
219650	368.67^{abc}	129.68	2.667	9.00	10.00	1185.00^{a}
200390	413.00^{abc}	101.33	2.000	10.00	8.33	1661.33^{ab}
Abaro	421.00^{ab}	114.33	2.667	9.21	9.67	1447.00^{ab}
219645	439.00^{a}	131.33	1.000	10.67	10.00	1222.33^{a}
106564	382.67^{abc}	114.68	2.667	11.67	9.33	1244.00^{a}
212631	343.33^{abc}	92.33	3.333	9.67	8.67	1232.00^{a}
Wolenchite	283.33^{bc}	90.00	2.333	11.00	10.33	1165.00^{ab}
*P*value	0.037	0.925	0.150	0.300	0.192	0.040
CV (%)	2.47	3.71	1.73	2.59	1.08	7.59

The means within a column followed by different letters are significantly different at $P < 0.05$ (the Tukey test).

Table 3: Effect of different castor genotypes on hatchability, fecundity, larval period, matured larval weight, life cycle, and effective rate of rearing (ERR).

Castor genotypes	Hatchability (%)	Fecundity	Larval period (day)	Larval weight (g)	Total life cycle (day)	ERR (%)
200390	92.68^{a}	294.00^{a}	22.00^{c}	5.93^{c}	58.00^{d}	94.54^{a}
Abaro	89.00^{a}	312.67^{a}	24.00^{a}	6.16^{a}	58.33^{d}	90.60^{ab}
219645	89.68^{a}	292.67^{a}	23.00^{b}	6.05^{b}	61.00^{abc}	88.32^{abc}
106564	86.00^{a}	282.00^{a}	22.00^{c}	5.83^{d}	58.33^{d}	82.79^{bc}
212631	88.52^{a}	294.34^{a}	23.00^{b}	6.12^{a}	62.33^{a}	82.40^{c}
219650	89.24^{a}	304.98^{a}	24.00^{a}	5.46^{c}	59.32^{bcd}	86.58^{bc}
219682	91.89^{a}	296.52^{a}	23.00^{c}	5.92^{c}	58.20^{d}	88.17^{abc}
219671	89.52^{a}	304.34^{a}	23.00^{b}	6.10^{a}	61.31^{ab}	87.22^{abc}
Wolenchite	89.14^{a}	314.98^{a}	24.00^{a}	5.46^{c}	59.32^{bcd}	86.48^{bc}
Local tepi	86.42^{a}	298.54^{a}	23.00^{b}	6.00^{a}	62.33a	82.40^{c}
*P*value	0.2676	0.5172	0.0001*	0.0001*	0.0302*	0.0074*
CV (%)	4.2132	8.239	0.0458	0.6742	1.833	5.540

The means within a column followed by different letters are significantly different at $P < 0.05$ (the Tukey test).

genotypes. This result agrees with Shifa [15] and Sarmah et al. [22], who observed a difference in leaf area due to the difference in castor genotypes.

This result also showed a significant ($P < 0.05$) difference in fresh leaf yield among the genotypes. The highest fresh leaf yield (439 g/10 fresh leaves) was recorded in the 219645 genotypes, whereas the lowest fresh leaf yield (258.33 g/10 fresh leaves) was obtained in Tepi local (Table 2). The variation in fresh leaf yield observed in this study may be due to genetic differences in the selected castor genotype. A similar study was conducted by Shifa [15] and Sannappa et al. [24], who found a significant difference in fresh leaf yield among castor genotypes in Ethiopia and India, respectively.

3.2. Effect of Different Castor Genotypes on Rearing Performance of Eri-Silkworm. The highest and lowest hatching percentages were recorded from silkworm fed on 200390 (92.68%) and 106564 (86.00%) genotypes, respectively. However, there was no significant difference observed among all treatments (Table 3). This result corroborates the finding of Sarkar et al. [25] who reported 90% to 85% hatchability of silkworms as a result of feeding on different castor genotypes. Besides, Sannappa et al. [26] also observed hatchability ranging from 98.05% to 98.92% from feeding on different castor genotypes. In another study, Shifa et al. [8] reported a significant variation in egg hatchability ranging from 81.50% to 95.33% of Eri-silkworm larvae fed on different castor genotypes. This difference in hatchability might be due to variations in environmental conditions and castor genotypes. Foliar constituents of the castor genotype have a direct correlation with the hatchability of Eri-silkworm [25, 27].

A significant difference was observed in the effective rate of rearing (ERR) when Eri-silkworm fed on different castor genotypes. The highest ERR was observed in Eri-silkworm fed on genotype 200390 (94.54%), followed by Abaro (90.60%), and genotype 219645 (88.32%), as described in Table 3. The variation in ERR of silkworms fed on different castor genotypes may be due to variations in foliar composition and nutrient availability in different genotypes which contribute to the growth and development of silkworms. A similar finding was reported by Chandrashekhar and Govindal [16], Shifa et al. [8], and Gurajala and Manjula [28], who observed variations in ERR because of variations in castor genotypes.

The present study also depicts that there was a significant difference in larval duration among Eri-silkworm larvae fed on different castor genotypes. Eri-silkworm fed on the 200390 and 106564 genotypes showed shorter larval duration (22 days). In addition, a significant difference was also

Table 4: Effect of different castor genotypes on cocoon, pupal and shell weight, and silk ratio.

Castor genotypes	Cocoon weight (g)	Pupal weight (g)	Shell weight (g)	Silk ratio (%)
200390	3.23^{c}	2.23^{c}	0.44^{bc}	13.62^{ab}
Abaro	3.16^{b}	2.33^{b}	0.43^{a}	13.61^{a}
219645	3.26^{a}	2.46^{a}	0.45^{b}	13.80^{ab}
106564	3.09^{d}	2.13^{d}	0.42^{c}	13.59^{b}
212631	3.12^{b}	2.21^{c}	0.41^{c}	13.14^{a}
219650	3.20^{a}	2.16^{b}	0.43^{a}	13.44^{ab}
219682	3.14^{b}	2.22^{c}	0.41^{c}	13.06^{a}
219671	3.21^{c}	2.18^{d}	0.42^{c}	13.08^{a}
Wolenchite	3.08^{d}	2.12^{d}	0.40^{c}	13.13^{a}
Local tepi	3.21^{a}	2.20^{c}	0.43^{a}	13.40^{b}
*P*value	0.0001^{*}	0.0001^{*}	0.0005^{*}	0.157
CV (%)	1.7959	1.1541	4.3153	2.306

The means within a column followed by different letters are significantly different at $P < 0.05$ (the Tukey test).

observed in the duration of the total life cycle of Eri-silkworm fed on different genotypes with the shortest life cycle of 58 days for the larvae fed on the 200390 genotypes (Table 3). A similar observation was reported by several authors [29–33], who reported different larval durations among silkworms because of the difference in castor genotypes. The variation recorded in the Eri-silkworms fed on different castor genotypes may be due to variations in the composition of foliar constituents of castor genotypes that contributed to differences in larval duration. Similarly, significant variation was observed in mature larval weight Eri-silkworm fed on castor genotypes ($P < 0.05$). Significantly, the highest larval weight was observed in Eri-silkworms fed with the Abaro genotype (6.16 g).

Table 4 depicts that significantly ($P < 0.05$) the highest cocoon weight (3.26 g) was recorded in Eri-silkworm fed with genotype 219645, while the lowest was in Wolenchite genotype (3.08 g). A significant difference was observed in the silk ratio, with a higher value recorded for the larvae fed on the 219645 genotypes (13.80%) (Table 4). This result is in line with the findings of Pandey [34], Ahmed [35], and Sarkar et al. [25], who reported variation in cocoon traits when different castor genotypes were offered as feed. In the present study, the highest shell weight (0.45 g) and pupal weight (2.46 g) were recorded in Eri-silkworms fed with the 219645 genotypes with significant variation ($P < 0.05$). However, the lowest shell weight (0.40 g) and pupal weight (2.12 g) were observed in Eri-silkworm fed on the Wolenchite genotype (Table 4). The variation in shell, pupae, and cocoon quality may be due to differences in the chemical composition of castor leaves of different genotypes [15, 36, 37, 38].

4. Conclusions and Recommendations

The current study revealed that different castor genotypes showed significant variations in agronomic performance under field conditions. Selection of castor genotypes based on leaf biomass showed that genotypes 219645, Abaro, and 200390 were better than the other castor genotypes for the rearing of Eri-silkworm. This study also indicated that castor genotypes have a strong influence on Eri-silkworm rearing performance. Thus, the selection of castor genotype is important to get the best larval development, cocoon, and silk yield. Genotype 219645 can be recommended for Eri-silkworm rearing and sericulture development in the future in the Tepi areas. Moreover, due to its high fresh leaf yield, genotype 200390 should be considered for future plant breeding work to increase the fresh leaf yield of a given genotype in combination with other agronomic performances. Further studies should continue to give more emphasis to the multi-location study of this castor genotype to understand how they perform in the diverse growing environment.

Data Availability

All data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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