Effect of castor leaves supplemented with seed flours of soybean, cowpea and amaranthus on larval and cocoon parameters of eri-silkworms (*Samia cynthia ricini*)

Beshada Taye* , Metasebia Terefe, Kedir Shifa, Aynalem Tsegaw, Abiy Tilahun, and Ahmed Ibrahim

Melkassa Agricultural Research Center, PO Box 436, Adama, Ethiopia

Received: 18 April, 2024 **Accepted:** 29 July, 2024 **Published:** 17 September, 2024

ABSTRACT

The growth, development, and silk yield of silkworms are highly affected by the quality of the leaves used as feed. In the present investigation, eri silkworms were fed flour supplements made from soybean (Glycine sp.), cowpea (Vigna sp.), and Amaranthus (*Amaranthus* sp.) seeds at concentration levels of 45 g/kg, 30 g/kg, and 15 g/kg of castor leaf, respectively. A control group was included with castor leaves and no supplementation. The experiment, comprising ten treatments, was laid out in a completely randomized design (CRD) with five replications at the Melkassa Agricultural Research Center (MARC) in the East Shewa Zone of Oromia Regional State, Ethiopia. The treatments were evaluated for their effects on important larval and cocoon parameters of eri silkworms (*Samia cynthia ricini* B.) using a white plain Eri silkworm breed known as Eri-3.4. Data analysis was conducted using SAS software at a 5% probability level. The treatment combinations showed significant differences among themselves, and the addition of leaf supplements in powder form improved various larval and cocoon parameters, including larval weight, effective rate of rearing, cocoon weight, pupal weight, shell weight, and shell ratio. Among the treatments, soybean at a rate of 45 g/kg of castor leaf and 30 g/kg of castor leaf, cowpea at 45 g/kg of castor leaf, and Amaranthus at 45 g/kg of castor leaf were found to be superior, yielding better results in terms of larval and cocoon parameters. Therefore, it can be concluded that applying powders made from the seeds of soybean, cowpea, and Amaranthus on castor leaves improves eri silkworm parameters and can be considered as basic inputs for supplementary feed in future silkworm rearing.

Keywords: Eri silkworms; *Samia cynthia ricini;* Castor; Supplement; Larval and cocoon parameters

DOI: https://dx.doi.org/10.4314/ejst.v17i2.1

INTRODUCTION

Sericulture is an agro-based popular cottage industry. It involves the rearing of silkworms for the production of raw silk, which is the yarn obtained from cocoons spun by certain species of insects (Lalmuankimi *et al*., 2020). Silk production has the potential to make a significant contribution to the economies of many countries where there is surplus labor, low production costs, and a willingness to adopt new technologies (Alipanah *et al*., 2020). Silk, a natural fiber admired for its beauty, softness, and radiant appearance, has fascinated humans for centuries (Board *et al*.,

*Corresponding author: taye.beshada22@gmail.com

©This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/CC BY4.0)

2023). Silkworms are fascinating creatures that have contributed immensely to silk production across the world (Board *et al*., 2023). Silk has had a strong affinity with the people of Ethiopia since the ancient period of the country's civilization (Dereje Tulu *et al*., 2022).

Increasing the quality and quantity of silk cocoons, as well as larval growth, would therefore be beneficial in meeting the production needs of related agro-industries and contributing to the improvement of the socio-economic position of silk farming communities (Ravikumar, 1988). The eri-silkworm, *Samia cynthia ricini* Boisduval, is reared by farmers, youth, and women's groups, as well as private investors, in different states of Ethiopia, including SNNP, Sidama, Oromia, Amhara, and Southwest Ethiopia. It is one of the most exploited and commercialized non-mulberry silkworms in the world, valued for its eri silk fiber and related byproducts (MoA, 2024). The eri-silkworm is a multivoltine and polyphagous species that can be reared throughout the year, depending on the availability of feed (Debaraj *et al*., 2003). Castor (*Ricinus communis* L.) is the primary feed plant, ensuring better growth of eri silkworms and the production of high-quality cocoons.

Feed is one of the factors that affect the productivity of *S. c. ricini* (Putra *et al*., 2023). Nutrition is an incremental factor that enhances insect growth and development, subsequently influencing cocoon production (Sampath *et al*., 2013). The nutritive quality of feeds plays an important role in the growth and development of worms, stabilizing cocoon production and silk productivity (Hassan, 2020).

To improve the quality of silk and the quantity of cocoons, it is necessary to enrich the nutrient quality of silkworm feed; this can be achieved by supplementing mulberry or castor leaves with additional nutrients (Hassan *et al*., 2020). Many plants have been confirmed to be effective in improving the various life stages of silkworms, such as increasing larval body weight, silk gland weight, cocoon weight, shell weight, and the maturation of silkmoths, which in turn enhances the economic benefits of silkworms (Singh and Saxena, 2015; Saad *et al*., 2019).

To increase cocoon production, the enrichment of castor leaves with supplementary compounds is critically important (Sujatha *et al*., 2014). Nutritional supplements, when added to standard food, not only increase the nutritional value of the food but also improve the vital parameters of the silkworm (Sujatha *et al*., 2014). The enrichment of castor leaves with supplementary nutrients such as proteins, carbohydrates, amino acids, vitamins, sterols, hormones, and antibiotics primarily enhances larval growth and cocoon production (Hassan, 2020). Fortifying castor leaves with soybean, cowpea, and other nutritious products will fulfill the nutritional needs of silkworms. Such options provide an economically viable technique that could improve cocoon characteristics and production. Soy protein is a rich source of dietary protein, and daily supplementation is known to enhance larval growth and elevate the economic traits of silkworms by increasing the quality and quantity of silk cocoon production (Kamaraj *et al*., 2017). Horie and Watanabe (1983) demonstrated that the supplementation of soybean protein increased the protein and amino acid content in the larval hemolymph of the silkworm. Considering these facts, an attempt was made to increase the growth of silkworms and cocoon yield using selected leguminous food additives. Therefore, an experiment was designed to determine suitable food additives for silkworms, with the objective of assessing the effect of nutritional supplementation of silkworm feed plants (castor leaves) with flours from the seeds of soybean, cowpea, and Amaranthus on the larval and cocoon parameters of eri-silkworms.

MATERIALS AND METHODS

Description of the study area

The study was conducted at the Melkassa Agricultural Research Center (MARC), located 117 km east of Addis Ababa and 17 km southeast of Adama in the East Shewa Zone of the Oromia region, Ethiopia. It is situated at 8°24'N latitude and 39°12'E longitude, with an elevation of 1,550 meters above sea level and a mean annual rainfall of 770 mm.

Experimental setup

Before starting the rearing process, the rearing room and equipment were thoroughly cleaned, and the floor was washed with a 5% bleaching powder solution. The entire room was disinfected by spraying with a 2% formalin solution (Dandin *et al*., 2003). The eri silkworm strain used for this experiment was the white plain Eri-3.4, which was available in our sericulture laboratory. Soybean seeds were obtained from the Jimma Agricultural Research Center, while cowpea and Amaranthus seeds were sourced from crop research teams at the Melkassa Agricultural Research Center.

Data collection methods

Castor leaves were used as the feed source for eri silkworms in the laboratory. According to the rearing protocols for silkworms (Dayashankar, 1982), a white plain eri-silkworm breed was used for this experiment, which was reared on one released castor genotype (Abaro). The silkworm rearing room and equipment were cleaned, washed, and disinfected with a 2%

formalin solution at a rate of 800 ml per 10 m^2 before the commencement of the experiment. This breed was reared following cellular rearing techniques, starting from brushing until cocoon spinning, using the same castor genotype with different legume flour supplementation. Tender leaves of castor were fed four times a day until the larvae reached the II instar stage, semi-tender leaves were provided to the III instar, while more mature leaves were given to IV and V instar larvae. The experiment was arranged in a completely randomized design (CRD) with five replications. In each replication, 50 worms were used and allowed to complete the larval period. Mature worms were picked and mounted on the mountages for spinning (Singh and Benchamin, 2002; Ramesha *et al*., 2010). On the sixth day of spinning, the cocoons were harvested, counted, and weighed.

The study focused on enriching castor leaves with soy flour, cowpea flour, and Amaranthus seed to improve silkworm nutrition. Experiments were conducted with eri-silkworms. Some plots of larvae were fed on non-treated or normal leaves starting from the third instar, which was considered a control, while the other plots were fed on treated or dusted leaves starting from the third instar up to the mounting stage. The required seeds of the supplement crops were collected and dried under shade. After drying, the dry powder was prepared using a mortar and pestle. The dry powder of Amaranthus seed, soy flour, and cowpea flour was dusted on the leaves in three different doses (45 g/kg of leaves, 30 g/kg of leaves, and 15 g/kg of leaves). Two hundred larvae were used for each treatment. When the larvae reached the third instar, the required quantities of soybean and cowpea flour, as well as Amaranthus seed powder, were weighed and mixed with castor leaves and fed at the beginning of the third instar stage of the larvae. This experiment was conducted in a completely randomized design (CRD) with five replications. The experimental treatments comprised the following combinations of diets:

T1 – Soybean flour 45 g/kg of castor leaf
T2 – Soybean flour 30 g/kg of castor leaf
T3 – Soybean flour 15 g/kg of castor leaf
T4 – Cowpea flour 45 g/kg of castor leaf
T5 – Cowpea flour 30 g/kg of castor leaf
T6 – Cowpea flour 15 g/kg of castor leaf
T7 – *Amaranthus* seed 45 g/kg of castor leaf
T8 – *Amaranthus* seed 30 g/kg of castor leaf
T9 – *Amaranthus* seed 15 g/kg of castor leaf
T10 – Control (castor leaf with no supplement)

Measures and records of the daily castor leaf supply weight, along with the calculated weight of supplemental powder from soybean, cowpea, and Amaranthus based on the required experimental ratios, were taken. Additionally, data were collected on the number of dead larvae, larval weight, cocoon weight, shell weight, pupal weight, and shell ratio.

Data analysis

The data for all biological parameters of the eri-silkworm were analyzed using SAS software at a 5% level of significance (SAS Institute Inc., 2020). Additionally, LSD (Least Significant Difference) was employed for mean separation of the ten feed supplementation treatments conducted during the III and V stages of eri-silkworm rearing.

RESULTS AND DISCUSSION

Effect on larval weight (g)

In this study, the weights of 10 larvae were measured on the 6th day of the 5th instar. Matured worms fed on castor leaves supplemented with 45 g of soybean/kg of castor leaf and 45 g of cowpea/kg of castor leaf recorded the highest larval weight (46.9 g), followed by the treatment with 30 g of cowpea/kg of castor leaf (46.4 g) and 30 g of soybean/kg of castor leaf (45.0 g). The least weight of the 10 larvae (38.7 g) was observed in the control group, which received castor leaves without any supplements (Figure 1).

The increased larval weight of silkworms in this study may be attributed to the availability of optimum proteins in the fortified castor leaves provided during the larval period. The results of the present study confirm the findings of Sharma *et al*. (2023), who reported that mulberry leaves fortified with Protinex (10%) and drone brood (5%) + Protinex (5%) significantly influenced the body weight of silkworm larvae. This result is also consistent with the findings of Himangshu Barman and Rama Krishna (2011), who revealed that in the 4th and 5th instars, larval weight was significantly higher in all treatments fortified with Phagostimulants Formulation spray solutions compared to the control group.

Effective rate of rearing (%)

In the current study, the effective rate of rearing was maximized with 45 g of flour per kg of castor leaf across all treatments. Specifically, 45 g of soybean/kg of castor leaf resulted in an effective rearing rate of 80.7%, 45 g of cowpea/kg of castor leaf yielded 75.9%, and 45 g of Amaranthus/kg of castor leaf achieved 75.7%, while the control group recorded 66.6% (Figure 2). These results align with the findings of Lalmuankimi *et al*. (2020), who reported that plant extracts had a significant effect on the effective rate of rearing of eri silkworms, with the highest effective rate observed when larvae were fed on castor leaves fortified with 10% Murraya koenigii leaf extracts. Additionally, the fortified castor leaves had a significant impact on the effective rate of rearing (ERR) compared to the untreated batch (Lalmuankimi *et al*., 2020).

Cocoon weight (g)

In the current study, high single cocoon weights were recorded with soybean flour at 30 g/kg of castor leaf (1.6612 g), cowpea flour at 45 g/kg of castor leaf (1.6994 g), and Amaranthus seed at 45 g/kg of castor leaf (1.6876 g) (Table 1). The single cocoon weight varied among the different treatments studied (i.e., supplementary feeds). These differences may stem from the varying nutrient contents among the supplementary feeds.

Similarly, Shifa (2016) reported that the supplementation of extra nutrients along with mulberry leaves resulted in higher yields, as the production of superior quality and quantity of silk primarily depends on the nutritional status and health of the larvae. Additionally, Mala and Vijila (2020) noted that the dietary efficiency of silkworms is a crucial factor for converting feed into commercially important silk. The concept of fortifying castor leaves is a sophisticated technique that enhances the nutritional value of the food, making it more beneficial for improving silkworm health, cocoon quality, and subsequent silk production.

Shell weight (g)

In the current study, the single shell weight of a cocoon showed significant improvement when worms were fed castor leaves with flour supplements of soybean, cowpea, and Amaranthus. The feed supplementation of 45 g of Amaranthus per kg of castor leaf resulted in the highest shell weight (0.249 g), followed by 45 g of cowpea per kg of castor leaf (0.2408 g) and 45 g of soybean per kg of castor leaf (0.2404 g), while the control group exhibited the least shell weight (0.1496 g) (Table 1).

This result aligns with the findings of Shivkumar *et al*. (2020), whose amino acid-treated mulberry leaves fed to silkworm larvae resulted in significantly higher body weight, cocoon weight, shell weight, and yield per 100 DFLs (kg) compared to the control group. Similarly, Kumar (2018) reported that silkworms nourished with mulberry leaves fortified with tryptophan at different concentrations strongly influenced shell weight. Furthermore, the findings by Poonguzali *et al*. (2021) on the utilization of plant seed powders during silkworm rearing indicated a promising approach for the integrated improvement of economic traits in the silkworm *Bombyx mori* L.

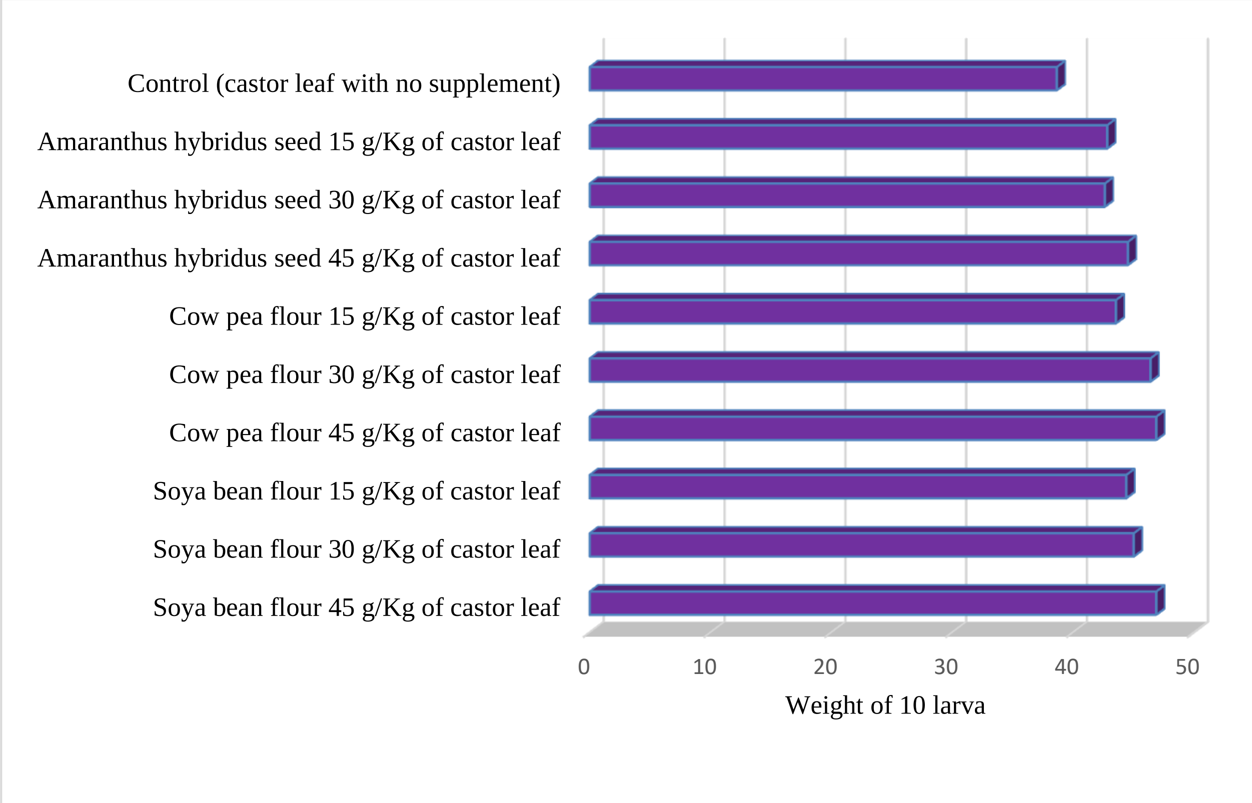

Figure 1. Effect on weight of 10 larvae observed by powder supplements of soybean, cowpea and Amaranthus

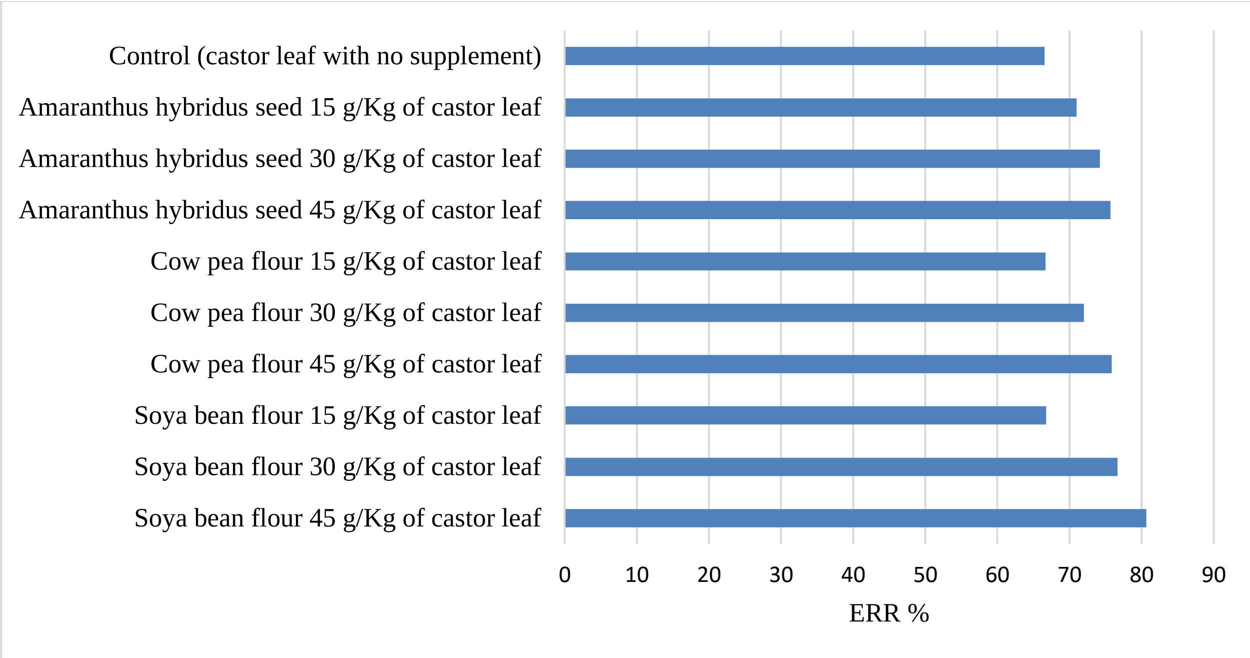

Figure 2. Effective rate of rearing (ERR) of an eri silkworm as influenced by powder supplements of soybean, cowpea and Amaranthus

Table 1. Mean effect castor leaf supplementation with flours of soybean, cowpea and Amaranthus seeds on cocoon, pupa and shell weights of Eri silkworms

Treatments	**Single cocoon weight (g)**	**Single pupal weight (g)**	**Single shell weight (g)**
Soybean flour 45 g/kg CL*	1.64±0.0062abc	1.40±0.0061abc	0.24±0.0002a
Soybean flour 30 g/kg CL	1.66±0.0061abc	1.43±0.0077abc	0.24±0.0027a
Soybean flour 15 g/kg CL	1.63±0.0324abc	1.41±0.0249abc	0.22±0.0030b
Cowpea flour 45 g/kg CL	1.70±0.0043a	1.46±0.0035a	0.24±0.0009a
Cowpea flour 30 g/kg CL	1.57±0.0171c	1.37±0.0176c	0.20±0.0045bc
Cowpea flour 15 g/kg CL	1.41±0.0230d	1.27±0.0110d	0.16±0.0077d
Amaranthus seed powder 45 g/kg CL	1.69±0.0326ab	1.44±0.0255ab	0.25±0.0037a
Amaranthus seed 30 g/kg CL	1.59±0.0807bc	1.39±0.0349bc	0.19±0.0114c
Amaranthus seed powder 15 g/kg CL	1.61±0.0449abc	1.41±0.040abc	0.19±0.0053c
Control (CL with no supplement)	1.27±0.0093e	1.12±0.0186e	0.15±0.0055d
CV	5.12	3.80	5.88
p-value	<.0001	<.0001	<.0001

Note: Means within the same column with a common letter are not significantly different ($P<0.05$), CV stands for coefficient of variation, *CL stands for castor leaf.

Silk shell ratio (%)

The present results (Table 2) indicated that the shell ratio was highest at 14.7% when castor leaves were used as feed with the supplementation of 45 g of Amaranthus seed powder per kg of castor leaf. This was followed by 45 g of soybean per kg of castor leaf (14.6%), 30 g of soybean per kg of castor leaf (14.2%), and 45 g of cowpea per kg of castor leaf (14.2%).

Table **2**. Mean effect castor leaf supplementation with flours of soybean, cowpea and Amaranthus seeds on Shell ratio of Eri silkworms.

Treatments	**Shell ratio (%)**
Soybean flour 45 g/kg of castor leaf	14.556±0.027a
Soybean flour 30 g/kg castor leaf	14.248±0.019a
Soybean flour 15 g/kg castor leaf	13.428±0.139b
Cowpea flour 45 g/kg castor leaf	14.190±0.0428a
Cowpea flour 30 g/kg castor leaf	12.988±0.3035b
Cowpea flour 15 g/kg castor leaf	11.458±0.4088d
Amaranthus seed powder 45g / kg of castor leaf	14.716±0.0682a
Amaranthus seed powder 30 g / kg of castor leaf	12.190±0.0931c
Amaranthus seed powder 15g/kg of castor leaf	12.198±0.2885c
Control (Castor leaf with no supplement)	09.800±0.1260e
CV	3.48
p-value	<.0001

Note: Means within the same column with a common letter are not significantly different (P<0.05

However, the lowest shell ratio (9.8%) was obtained when eri silkworms were fed on castor leaves without any nutritional flour supplementation (control). The increase in the shell ratio may be attributed to enhanced silk productivity from the additional supplementation of soybean, cowpea, and Amaranthus flour. According to Borah and Boro (2020), larvae fed a diet containing soybean throughout the 5th instar exhibited the highest results in terms of weights of larvae, silk gland, pupa, cocoon, and cocoon shell, as well as larval duration and the lowest mortality rates of the silkworm.

Similar results were reported previously, such as by Krishnappa (1987), who found that silkworms reared on mulberry leaves supplemented with glycine at a concentration of 1.5% enhanced shell ratio. Kumar (2018) also noted that silkworms nourished with mulberry leaves extra-fortified with tryptophan had a marked influence on shell percentage.

CONCLUSION AND RECOMMENDATION

The present study revealed that the selection of feed additives and the determination of their ratios for rearing eri silkworms are vital for achieving better larval development and cocoon silk production. The larval and cocoon performance data indicated that soybean seed flour supplementation at a rate of 30 g/kg of castor leaf or 45 g/kg of castor leaf, as well as cowpea seed flour supplementation at 45 g/kg of castor leaf or Amaranthus seed powder supplementation at 45 g/kg of castor leaf, were the best treatment options compared to other treatments.

Therefore, these supplements can be recommended for application on castor leaves for eri silkworm rearing in agro-ecologically similar areas to the environment of the Melkassa Agricultural Research Center, which may represent the semi-arid rift valley region of Ethiopia. However, further research should be conducted to validate the current findings, taking into consideration other agro-ecologies, nutrient profiling systems, and feeding efficiency.

ACKNOWLEDGEMENTS

We would like to express our sincere thanks to the Ethiopian Institute of Agricultural Research and the team members of the National Sericulture Research Program at the Melkassa Agricultural Research Center for their support and contributions to this study.

CONFLICT OF INTEREST

The authors declare no competing interests.

REFERENCES

Alipanah, M., Abedian, Z., Nasiri, A and Sarjamei, F. (2020). Nutritional effects of three mulberry varieties on silkworms in Torbat heydarieh. *Psyche: A Journal of Entomology* **2020:** 1–4.

Mehta, V., Harishkumar, J., Nitika, N and Himanshu, T. (2023). Storage entomology and beneficial insects*:* An overview walnut publication, 1-358.

Borah, S and Praban, B. (2020). A Review of nutrition and its impact on silkworm. *Journal of Entomology and Zoology Studies* **8**(3):1921–25.

Dandin, S.B., Jayant Jayaswal and K. Giridhar. (2003). Handbook of sericulture technologies. Central Silk Board, Bangalore.

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

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

Dereje Tulu, Melkam Aleme, Gezahegn Mengistu, Ararsa Bogale, Kedir Shifa, and Esayas Mendesil. (2022). 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. *Psyche: A Journal of Entomology* **2022**(3): 1–7. DOI: 10.1155/2022/1556776

Fukuda, T., Kamegame, T and Matsuda, M. (1963). A correlation between the mulberry leaves consumed by the mulberry silkworm larvae in different ages of the larval growth and production of cocoon fiber spun by silkworm larvae and the eggs laid by the silkworm. *Bulletin of the Sericulture Experiment* Station **18**:165–171.

Hassan, E. M. (2020). Comparative study on effects of some high protein content nutritional additives on some hybrids of mulberry silkworm, *Bombyx mori* L. *Journal of Plant Protection and Pathology* **11**(8): 403–410. doi: 10.21608/jppp.2020.114587.

Hassan S.I, Rateb, S.H., Mohanny, K.M and Hussein, M.H. (2020). Efficiency of some plants powder mix as a dietary supplement for silkworm (*Bombyx mori* L.). SVU-*International Journal of Agricultural Science* **2**(2): 378–83. doi: 10.21608/svuijas.2020.41808.1034.

Himangshu, B and Rama, K. (2011). Studies on effects of nutrient supplements fortified with phagostimulants formulation h1 on growth and development of indoor reared on *Antheraea assamensis* Helfer (Lepidoptera: Saturniidae). *International Journal of Biology* **3**(1): 167–173.

Horie, Y and Watanabe, K. (1983). Design of the composition of the artificial diet for the silkworm *Bombyx mori* by linear programming method: Application of ingredients of feed for domesticated animals and fowls. *Bulletin of Sericulture Experiment Station* **26:** 259–283.

Jayaramaiah, M and Sannappa, B. (1998). Correlation coefficients between foliar constituents of castor genotypes and economic parameters of the eri silkworm, *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae). Proceedings of the 3rd International Conference on Wild Silkmoths, November 11-14, 1998, Bhubaneshwar, India.

Kamaraj, S., Pandiaraj, T., Immaual, G.P., Sanju, K and Sinha, A.K. (2017). Effect of soya protein enriched fortified feed of Tasar silkworm (*Antherea mylitta* Drury) on rearing performance and economical cocoon characters. *International Journal of Advanced Biotechnology Research* **7**(1): 61–64

Krishnappa, J.B. (1987). Influence of amino acids supplementation on growth and development of mulberry silkworm, *Bombyx mori* L. M.Sc. Thesis, UAS Bangalore, p. 128.

Krishnaswami S., Narasimhanna, M.N., Suryanarayana, S.K and Kumararaj, S. (1977). Manual on sericulture-2, Silkworm Rearing, FAO, Rome.

Kumar, M.N. (2018). Application of tryptophan as supplementary nutrient on dehydrogenase activities and economic parameters in *Bombyx mori* L. *Journal of Pharmaceutical, Chemical and Biological Sciences* **6**(3): 209–217.

Lalmuankimi, C., Gogoi, I and Singha, T.A.. (2020). Effect of plant extracts on larval growth parameters of eri silkworm, *Samia ricini* Boisd. *International Journal of Current Microbiology and Applied Sciences* **9**(12): 2655–2661.

MoA (2024). National sericulture development strategy for Ethiopia. Ministry of Agriculture (MoA), Addis Ababa. 18 pp.

Mala, N and Vijila, K. (2021). Effect of feed fortification on nutritional indices traits of silkworm, *Bombyx mori* L. International Journal of Chemical Studies **9**(6): 18–23.

Poonguzali, J., Porkodi, E and Vimala, G. (2021). The effect of plant seed powders supplementation on feed efficiency and economic parameters. *Journal of Emerging Technologies and Innovative Research* **8**(11): 504–523.

Putra, S., Fuah, A.M and Endrawati, Y.C. (2023). Production performance of eri silkworm (*Samia cynthia ricini*) with cassava leaves feed (*Manihot utilissima*) on different mountages media. *Journal of Animal Production & Processing Technology* **11**(3): 170–175.

Rahmathulla, V.K., Priyabrata Das, Ramesh, M and Rajan, R.K.. (2007). Growth rate pattern and economic traits of silkworm, *Bombyx mori* L under the influence of folic acid administration. *Journal of Applied Science and Environmental Managemant* **11**(4): 81 –84.

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

Ravikumar, C. (1988). Western- Gharts as a bivoltine region prospects, challenges and strategies for its development. *Indian Silk* **26**(9): 39–54.

Saad, M.S., Elyamani, E.M and Helaly, W.M. (2019). Controlling of bacterial and fungal diseases that contaminating mulberry silkworm, *Bombyx mori* by using some plant extracts. *Bulletin of the National Research Centre* **43**(1): 172.

Sahayaraj, Kitherian. (2021). Coal fly ash liquid on growth amendments of eri silkworm and amelioration of horticulture crops. Crop Protection Research Centre (CPRC), Department of Zoology, St. Xavier's College, India.

Sampath, A., M. Ramesh Babu, K. Sujatha, R. S. Jaikishan Singh, B. Digamber Rao, and Regional Tasar. (2013). Beneficial effect of *Cyanobacteria anabaena variabilis* on quantitative traits of eri silkworm *Samia cynthia ricini*, Boisduval. *Asian Journal of Agricultural Sciences* **5**(3): 36–39.

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

Scriber, J.M and Slansky, F. (1981). The nutritional ecology of immature insects. *Annual Review of Entomology* **26**: 183–211.

Senft, J.P. (1980). Protein quality of amaranth grain. In: Proceedings Amaranth Conference, 2nd, 1979. Emmaus: Rodale Press, pp 43–47

Sharma, Arti, Palvi Sharma, R.S. Bandral, R.K. Gupta, and Kamlesh Bali. (2023). Influence of protein fortification on larval growth parameters of silkworm, *Bombyx mori* L. *The Pharma Innovation Journal* **12**(3): 2978–2982.

Shifa, V. (2016). Influence of supplementation of *Zea mays* flour on the growth and economic traits of silkworm, *Bombyx mori* L. (PFD). *IRA-International Journal of Applied Sciences* **3**(03): 469–478.

Shivkumar, Kumar, N.B., Ravindra, M.A., Mir, N.A and Chowdhury, S.R. (2020). Supplement of amino acids on mulberry leaf influence the cocoon yield and silk production in the temperate region of Jammu and Kashmir. *Research Journal of Agriculture Science* **11**(1): 87 – 91.

Singh, K.C and Benchamin, K.V. (2002). Biology and ecology of the eri-silkmoth *Samia ricini* Donovan (Saturniidae). *Bulletin Indian Academy of Sericulture* **6**: 20–33.

Singh, V.K and Saxena, A. (2015). Studies on the effect of the chloroform extract of *Ocimum basilicum* (Family: Lamiaceae) on the III and V instar larvae of silkmoth *Bombyx mori* L. (Family: Bombycidae). *Online International Interdisciplinary Research Journal* **5**(5): 53–60.

Subburathinam, K.M., Janarathanan, S and Krishnan, M. (1992). Nutritional response of mulberry silkworm to different levels of soya bean protein. Abstract of National Conference of Mulberry Sericulture Research held on Dec. 10-11, 1992, CSR&TI, Mysore, India.

Sujatha, K., Jaikishan, R.S., Sampath, A and Rao, B.V.S. (2014). Food consumption and utilization efficiency in *Samia ricini* Donovan reared on *Ricinus communis* Lin. leaves supplemented with cyanobacteria. *International Journal of Industrial Entomology* **28**(2): 32–38.