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EVALUATION OF GROWTH AND SILK QUALITY PRODUCED BY *Samia cynthia ricini* (LEPIDOPTERA: SATURNIIDAE) FED DIFFERENT LEAVES

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ABSTRACT

Samia cynthia ricini Donovan (Lepidoptera), commonly known as the eri silkworm, is spread in India, Japan, China, and Indonesia. Previous research showed that silk quality produced by the species is comparable to mulberry silk. The eri silk has many generations per year (multivoltine) and feeds on several species of plants, making them easy to cultivate. The larvae consist of five instars, and each instar needs 3-7 days, and the pupa stage is 7-9 days, while the adults can live for up to seven days. In this study, the effect of different feeds, i.e., *Manihot glaziovii* Mull. Arg., *Manihot esculenta* Crantz, *Cnidoscolus aconitifolius* Miller I. M. Johnston and *Terminalia catappa* Linn. on larval growth and silk quality of *S. ricini* was examined. The mating duration and oviposition of moths were also studied. Observations consist of larvae and pupae growth, silk quality, adult characteristics, mating duration and oviposition. The results showed the length and the weight of the larvae among treatments were significantly different ($P<0.05$), except the larvae fed by *M. glaziovii* and *M. esculenta* ($P=0.078$ and $P=0.38$). Meanwhile, the cocoon length and weight and fiber tensile strength and diameter among treatments were not significantly different ($P>0.05$). The head, thorax, and abdomen lengths between feed treatments in male and female showed no significant difference ($P>0.05$). Meanwhile, the forewings and hindwings length of male and hindwings length of female between treatments differed significantly ($P<0.05$). The stage of mating behavior consists of calling, courtship, copulation, and oviposition. Total mating duration among treatments showed that each feeding treatment was not significantly different ($P>0.05$). *Manihot glaziovii* feed treatment also showed the highest fecundity (70-290 eggs), while the lowest eggs fecundity was in *Terminalia cattappa* (66-279 eggs).

Keywords: Eri silk moth, nutrient contents, silk strength; oviposition; caterpillar

ABSTRAK

Samia cynthia ricini Donovan (Lepidoptera), biasanya dikenali sebagai ulat sutera eri, tersebar di India, Jepun, China, dan Indonesia. Penyelidikan sebelum ini menunjukkan bahawa kualiti sutera yang dihasilkan oleh spesies ini adalah setanding dengan sutera mulberi. Sutera eri mempunyai banyak generasi setahun (multivoltin) dan memakan beberapa spesies tumbuhan, menjadikannya mudah untuk diternak. Larva terdiri daripada lima instar, dan setiap instar memerlukan 3-7 hari dan peringkat pupa adalah 7-9 hari, manakala dewasa boleh hidup sehingga tujuh hari. Dalam kajian ini, kesan makanan yang berbeza, iaitu, *Manihot glaziovii* Mull. Arg., *Manihot esculenta* Crantz, *Cnidoscolus aconitifolius* Miller I. M. Johnston dan *Terminalia catappa* Linn. terhadap pertumbuhan larva dan kualiti sutera *S. ricini* telah dikaji. Tempoh mengawan dan oviposisi rama-rama juga dikaji. Pemerhatian terdiri daripada pertumbuhan larva dan pupa, kualiti sutera, ciri dewasa, tempoh mengawan dan oviposisi. Hasil kajian menunjukkan panjang dan berat larva antara rawatan adalah berbeza secara signifikan ($P<0.05$), kecuali larva yang diberi makan dengan *M. glaziovii* dan *M. esculenta* ($P=0.078$ dan $P=0.38$). Sementara itu, panjang dan berat kokon serta kekuatan tegangan dan diameter gentian antara rawatan adalah tidak berbeza secara signifikan ($P>0.05$). Sementara itu, panjang sayap depan dan sayap belakang jantan dan panjang sayap belakang betina antara rawatan berbeza secara signifikan ($P<0.05$). Peringkat kelakuan mengawan terdiri daripada panggilan, *courtship*, kopulasi dan oviposisi. Jumlah tempoh mengawan antara rawatan menunjukkan bahawa setiap rawatan pemberian makanan tidak berbeza secara signifikan ($P>0.05$). Rawatan suapan *M. glaziovii* juga menunjukkan kesuburan yang paling tinggi (70-290 biji), manakala kesuburan telur yang paling rendah adalah di *Terminalia cattappa* (66-279 biji).

Kata kunci: Rama-rama sutera Eri, kandungan nutrien, kekuatan sutera, oviposisi, ulat bulu

INTRODUCTION

Natural silk agro-industry activity includes several stages, such as planting trees as a fed source of silkworm, breeding activity, cocoon processing, fiber spinning, and silk weaving (Ministry of Forestry, Republic of Indonesia 1999). Generally, silk fiber in Indonesia is produced by the *Bombyx mori* L. As a monophagous species, the larvae of *B. mori* only fed of mulberry plant, making it difficult to procure food for the cultivation. Silk of *B. mori* is produced by cocoons processing cause a death of pupa. The specialty of silk fiber cannot be replaced by artificial silk fiber (Nuraeni & Putranto 2007).

The Eri silkworm (*Samia cynthia ricini* Donovan) (Lepidoptera: Saturniidae) is distributed in India, Japan, and China (Bala et al. 2016). The species has many generations per year (multivoltine) (Shifa et al. 2015). The Eri silkworms are oligophages, which consume leaves of several plant species, especially leaves that are not too hard or not hairy (Ihsan et al. 2022; Tungjitwitayakul & Tatun 2017). This species has a complete metamorphosis consisting of eggs, larvae, pupae, and adults (Atmosoedarjo et al. 2000). The larvae consist of five instars, with a duration of each instar is 3-7 days. The pupal stage lasts for 7-9 days, while the adult life span is 2-7 days (Shifa et al. 2015). The growth and development of silkworms are influenced by several factors, such as the quality of leaves that affect the fiber quality (Setiyawan & Fitasari 2018). This study described the effect of different feeds, i.e., *Manihot glaziovii*, *Manihot esculenta*, *Cnidoscolus aconitifolius*, and

Terminalia catappa on growth of the eri silkworm. The mating duration and oviposition of the species were also observed.

MATERIALS AND METHODS

Rearing of Silkworm

Four plant species were used to feed the silkworm, i.e., *Manihot glaziovii*, *Manihot esculenta*, *Cnidoscolus aconitifolius*, and *Terminalia catappa*. Four plastic containers, each sized 47 cm x 30 cm x 13.5 cm, were used and each container contains 50 eggs of *S. ricini* as a cohort. The larvae emerged in each container were fed the leaves of each plant species four times a day. The total leaves used of *M. glaziovi, M. esculenta, C. aconitifolius,* and *T. cattappa* during the larvae rearing were approximately 20, 30, 25, and 20 leaves, respectively. The containers were kept and cleaned regularly. The air temperature and humidity of the rearing site were measured daily using 4-in-1 Lutron LM-8000A environment measurement. The 5th instar larvae were then transferred to suitable cages for cocooning process.

Measurement of Larvae, Pupae and Adults

The measuring of the caterpillars was conducted a day after the molting. The body length and weight of each instar (1st, 2nd, 3rd, 4th, and 5th instars) of each treatment (50 larvae) were measured. The length and diameter of the cocoon of each treatment (50 cocoons) were also measured using a caliper. For the adults, the head length, thorax length and abdominal length, a fore- and hind wingspan of 50 males and 50 females of each treatment were measured.

Silk Fiber Spinning

Cocoon is the final product of silkworm cultivation, it serves as a protective shelter for the larva metamorphosis to imago. Cocoon contains silk fibers produced through the process of fiber spinning, which involves the degumming process. The fiber degumming aims to separate the silk fibers from their adhesive substance called sericin. The degumming process follows the method described by Endrawati et al. (2017) that have degumming formula were NaOH 0.018 N and 110.53 °C for 55.51 minutes.

Measurement of Fiber Tensile Strength

A degumming process was conducted to obtain a single fiber. The tensile strength of the single fiber was tested at the Advanced Characterization Laboratory, National Research and Innovation Agency (BRIN), Cibinong, Indonesia. A single fiber sample was prepared using duplex paper glued to support the sample. The tensile strength test was carried out for three repetitions for each treatment. Fiber diameter was also measured by using a Dino-Lite digital portable microscope.

Proximate Analysis

Each leaf of caterpillar feed was analyzed using proximate analysis following the AOAC (2005) guidance. This analysis encompassed the determination of water, ash, crude fiber, protein, carbohydrate, and fat contents. This analysis was conducted at the Center for Biological Resources and Biotechnology Research, IPB University, Bogor, Indonesia.

Observation of Mating Duration and Oviposition

The male and female adults emerged from the cocoon were transferred into the gauze cage (60 cm x 60 cm x 75 cm) and paired male and female with a ratio of 3:1. The observations consisted of the duration of mating, duration of calling and courtship, and copulation behavior. The observation used three pairs of adults for each treatment. After mating completed, the male was removed and the female is left in the cage to observe its egg-laying behavior. The oviposition was observed in three different females for each treatment, and the number of eggs laid was observed daily.

Data Analysis

For data analysis, the pairwise Wilcoxon and the Kruskal-Wallis tests were employed using R Studio software (R Core Team 2016). This method was applied to analyze all measured parameters of larva *S. ricini*, pupa, and adult. The quantitative characteristics of cocoon and the tensile strength of silk fibers were described and compared, respectively.

RESULTS

Environmental Conditions of Rearing Site and The Larval Growth

The average temperature and humidity in the rearing site of *S. ricini* were 27.9°C and 85.7%, respectively. Those conditions are suitable for the culture of small caterpillars. The growth stage of *S. ricini* consisting of eggs, larvae (five intars), pupae, and adults. The current study showed the best growth (body length and weight) was found in larvae fed by the leaves of *M. glaziovii,* followed by *M. esculenta, C. aconitifolius*, and *T. cattappa*, respectively (Figure 1).

The larvae fed by *M. glaziovii* leaves showed the longest body length and highest body weight in all instars. In 5th instar, the highest body length was the larvae fed by *M. glaziovii* (5.74 ± 0.15 cm), followed by *M. esculenta* (5.66 ± 0.24 cm), *C. aconitifolius* (5.40 ± 0.28 cm), and *T. cattappa* (5.18±0.29 cm), respectively. Meanwhile, the highest weight of 5th instar was larvae fed by *M. glaziovii* (3.12 ± 0.15 g), followed by *M. esculenta* (3.07 ± 0.15 g), *C. aconitifolius* (2.96 ± 0.20 g), and *T. cattappa* (2.86 ± 0.21 g), respectively (Figure 1). Based on proximate analysis, leaves of *M. glaziovii* has the highest carbohydrate content (14.34%), while the lowest was found in *C. aconitifolius* (12.86%). Similarly, leaves of *M. glaziovii* also has the highest protein content (8.28%), while the lowest was found in *T. cattappa* (Table 1). This indicated that the quality of the feed influenced the growth and development of silkworms.

Table 1. The proximate analysis of leaves as a larval feed of *Samia cynthia ricini*

Feed	Water (%)	Ash (%)	Fat (%)	Protein (%)	Fiber (%)	Carbohydrate (%)
Manihot esculenta	75.92	1.52	0.92	7.60	3.27	14.06
Manihot glaziovii	74.65	1.99	0.82	8.26	3.01	14.29
Cnidoscolus aconitifolius	78.13	2.07	1.25	5.80	2.34	12.77
Terminalia cattappa	81.11	1.60	0.35	2.46	3.23	14.50

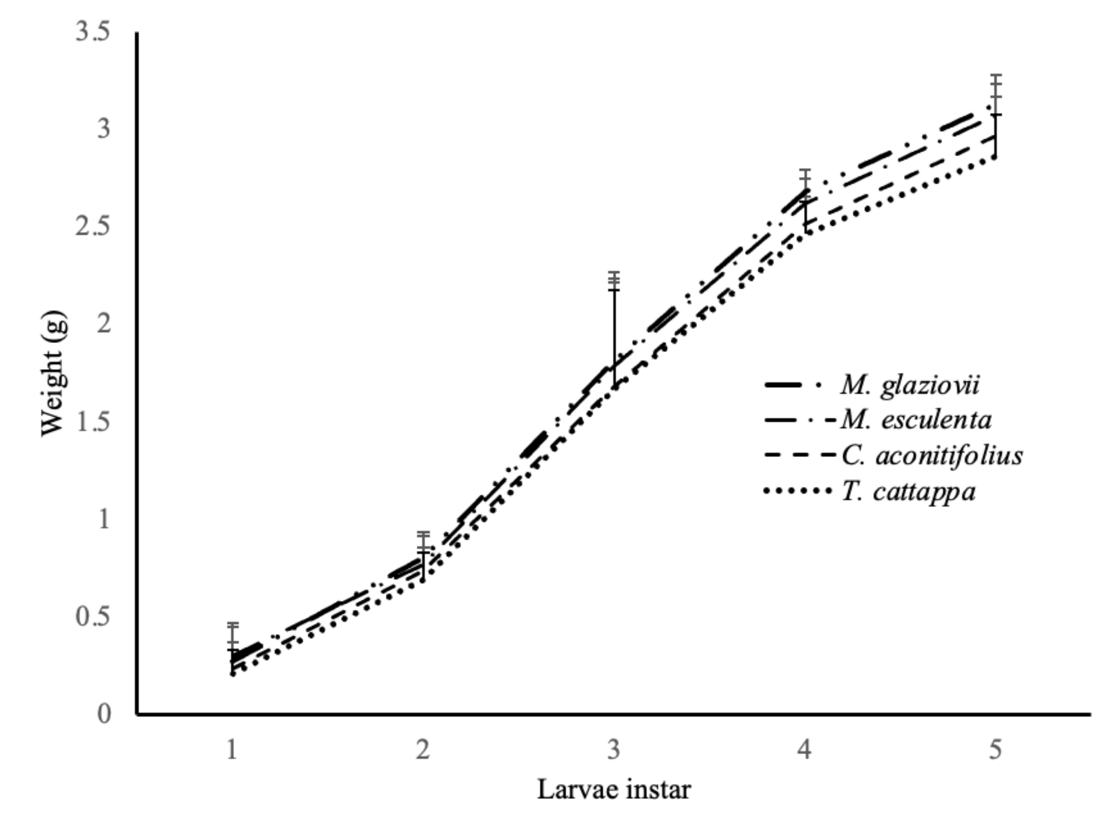

Figure 1. The weight larvae of *Samia cynthia ricini* on different larval fed treatment. Standard deviations were shown in each graph

Cocoon Characteristics and Fiber Tensile Strength of Fiber

The longest cocoon was found in the larvae fed by *M. glaziovii* (4.81±0.78 cm), while the shortest (4.55±0.63 cm) was provided by *T. cattappa*. Similarly, the largest cocoon diameters (1.24±0.32) also was found in the *larvae* fed by *M. glaziovii*, while the smallest (1.11±0.01) fed by *T. cattappa*. The Kruskal-Wallis test showed the cocoon length was not significantly different (*P>0.05*), while the cocoon weight produced by larval fed by *M. esculenta* was significant different with *C. aconitifolius* (*P=0.006*). The cocoon diameters produced by larval fed by *T. cattappa* was smallest than other treatments (Table 2).

Table 2. The cocoons characteristics of *Samia cynthia ricini* at different treatments. Means with the same letters in same row are not significantly different (*P>0.05*) using Kruskal-Wallis followed by Mann-Whitney test

Cocoon Characteristics	**Food plants**			
	Manihot glaziovii	***Manihot esculenta***	***Cnidoscolus aconitifolius***	***Terminalia cattappa***
Cocoon length (cm)	4.81 ± 0.78^{a}	4.66 ± 0.70^{a}	4.79 ± 0.79^{a}	4.55 ± 0.63^{a}
Cocoon weight (g)	1.55 ± 0.23^{ab}	1.55 ± 0.15^{a}	1.47 ± 0.16^{b}	1.51 ± 0.14^{ab}
Anterior cocoon diameter (cm)	1.24 ± 0.32^{ac}	1.23 ± 0.08^{b}	1.16 ± 0.03^{ac}	1.11 ± 0.01^{d}
Medial cocoon diameter (cm)	1.58 ± 0.35^{cd}	1.74 ± 0.21^{a}	1.61 ± 0.16^{b}	1.56 ± 0.23^{cd}
Posterior cocoon diameter (cm)	1.40 ± 0.04^{ab}	1.39 ± 0.05^{ab}	1.28 ± 0.03^{c}	1.25 ± 0.01^{d}

The tensile strength of single fiber was higher in larvae fed by *M. glaziovii* (77.8 Mpa), followed by *T. cattapa* (55.4 Mpa), *M. esculenta* (45.1 Mpa), and *C. aconitifolius* (34 Mpa), respectively, although based on the Kruskal-Wallis test it was not showed significant difference (*P>0.05).* Single fiber produced by larvae fed of *M. glaziovii, M. esculenta, T. cattappa* had a smaller diameter (0.05 mm) than *C. aconitifolius* (0.06 mm). The larvae fed by *C. aconitifolius* had a highest extensibility (23.9%), followed by *M. glaziovii* (18.9%*), T. cattapa* (22.1%), and *M. esculenta* (13.8%), respectively, although based on statistics analysis was not significant difference (Table 3).

Table 3. The single fiber tensile strength of *Samia cynthia ricini* on different treatments (feeds). Means with the same letters in same row are not significantly different (*P>0.05*) using Kruskal-Wallis followed by Mann-Whitney test

Fiber Characteristics	**Food plants**			
	Manihot glaziovii	***Manihot esculenta***	***Cnidoscolus aconitifolius***	***Terminalia cattappa***
Diameter (mm)	0.05^{a}	0.05^{a}	0.06^{a}	0.05^{a}
Maximum load (N)	0.1^{a}	0.1^{a}	0.11^{a}	0.12^{a}
Tensile strength (Mpa)	77.8^{a}	45.1^{a}	34^{a}	55.4^{a}
Extensibility (%)	18.9^{a}	13.8^{a}	23.9^{a}	22.1^{a}

Adult Characteristics

In general, the adult characteristics **(**morphometrics) of male *S. ricini* was smaller than those of female, as indicated in Table 4. Among the various feed treatments, the use of *M. glaziovii* as feed resulted in the biggest size of moth for both male and female individuals. The head, thorax, and abdomen lengths between feed treatments in male and female showed no significant difference (*P>0.05*). Meanwhile, the forewings and hindwings length of male and hind-wing length of female between treatments differed significantly (Table 4).

Table 4. The characteristics of adult *Samia cynthia ricini* on different treatments (leaves). Means with the same letters in same row are not significantly different (*P>0.05*) using Kruskal-Wallis followed by Mann-Whitney test

Parameters	**Female Moth**			
	M. glaziovii	***M. esculenta***	***C. aconitifolius***	***T. cattappa***
Head length (cm)	0.42 ± 0.06^{a}	0.41 ± 0.09^{a}	0.42 ± 0.10^{a}	0.4 ± 0.10^{a}
Thorax length (cm)	1.42 ± 0.08^{a}	1.41 ± 0.08^{a}	1.41 ± 0.07^{a}	1.41 ± 0.07^{a}
Abdomen length (cm)	1.47 ± 0.04^{a}	1.48 ± 0.04^{a}	1.48 ± 0.04^{a}	1.48 ± 0.05^{a}
Fore-wing length (cm)	5.47 ± 0.12^{a}	5.48 ± 0.07^{a}	5.48 ± 0.08^{a}	5.51 ± 0.03^{a}
Hind-wing length (cm)	4.49 ± 0.04^{bc}	4.49 ± 0.05^{cd}	4.51 ± 0.03^{a}	4.51 ± 0.04^{ad}
	Male Moth			
Head length (cm)	0.38 ± 0.04^{a}	0.38 ± 0.04^{a}	0.37 ± 0.03^{a}	0.38 ± 0.06^{a}
Thorax length (cm)	1.34 ± 0.03^{a}	1.34 ± 0.05^{a}	1.34 ± 0.01^{a}	1.34 ± 0.03^{a}
Abdomen length (cm)	1.43 ± 0.02^{a}	1.42 ± 0.01^{a}	1.42 ± 0.01^{a}	1.42 ± 0.01^{a}
Fore-wing length (cm)	5.44 ± 0.1^{a}	5.43 ± 0.04^{bc}	5.43 ± 0.03^{cd}	5.44 ± 0.02^{d}
Hind-wing length (cm)	4.41 ± 0.03^{ab}	4.41 ± 0.03^{b}	4.42 ± 0.02^{a}	4.42 ± 0.06^{a}

Mating Duration and Oviposition

The stages of mating, i.e., calling, courtship, and copulation have different duration. The calling duration ranged 5 to 5.03 minutes, courtship ranged 2.03 to 2.13 minutes, and copulation ranged 913 to 926 minutes. Meanwhile, the duration of oviposition ranged from 9 to 9.15 minutes and the total duration of mating ranged 929.08 to 942.21 minutes. The Kruskal-Wallis test showed the duration of calling, courtship, copulation, oviposition, and total duration among feed treatments was not significantly different (Table 5). Results showed that the highest egg fecundity was found in Samia fed by *M. glaziovii* (70-290 eggs), while the lowest fecundity was found in *T. cattappa* (66-279 eggs) (Figure 2).

Table 5. Mating duration of *Samia cynthia ricini* produced from larval fed on different plants. Means with the same letters in same row are not significantly different (*P>0.05*) using Kruskal-Wallis followed by Mann-Whitney test

Stage Duration	Plants used as food			
	Manihot glaziovii	***Manihot esculenta***	***Cnidoscolus aconitifolius***	***Terminalia cattappa***
Calling (minutes)	5.03	5	5.1	5
Courtship (minutes)	2.12[a]	2.03[a]	2.03[a]	2.8[a]
Copulation (minutes)	923[a]	920[a]	926[a]	913[a]
Oviposition (minutes)	9.2[a]	9.15[a]	9.08[a]	9[a]
Total duration (minutes)	939.35[a]	936.18[a]	942.21[a]	929.08[a]

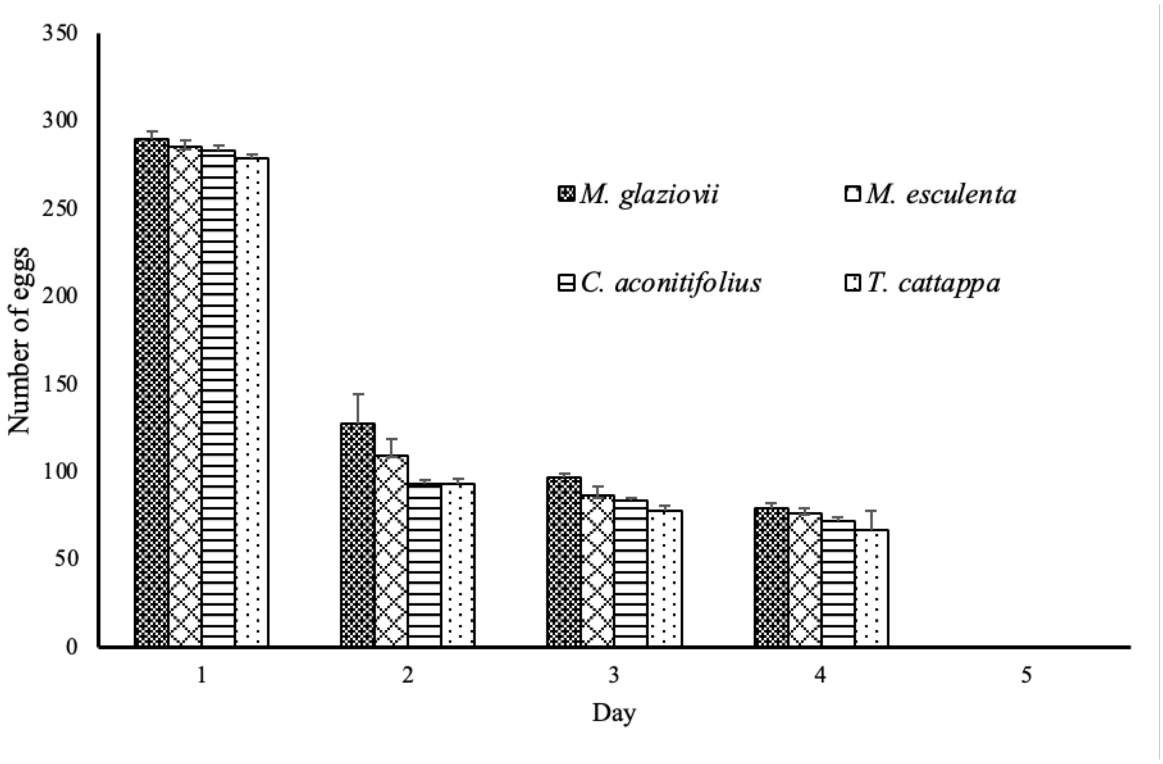

Figure 2. Number of eggs oviposited by female moth of *Samia cynthia ricini* on each food plant. Standard deviations were shown in each graph

DISCUSSION

The growth and development of *S. ricini* are influenced by several factors, including environment, climate, and egg and feed quality (Setiyawan & Fitasari 2018). Air humidity and room temperature are crucial environmental factors for the growth and development of *S. ricini* silkworms. In the 90% of humidity and the temperature ranged 26°C to 28°C, the larvae of silkworms still survive (Rahmathulla 2012), but it is important to keep the humidity in the range of 75% in the molting stage (Hailu et al. 2018). Renuka & Shamitha (2014) reported the optimal temperature for the growth of small silkworm (1^{st}, 2^{nd}, 3^{rd} instars) were 26-28°C with a relative humidity of 85%-90%, while for large caterpillars (4^{th} and 5^{th} instars) required lower temperature and humidity (24-26°C and 70%-80%, respectively). Brahma (2015) also stated the optimum temperature for growing the silkworm *S. ricini* ranged 20 to 40°C.

The optimum temperature and humidity required for rearing of *S. ricini* 1^{st}–4^{st} instar larvae are 26-28°C and 85-90%, respectively, while for 5^{th} instar larvae is 24-26°C and 70-80%, respectively (Singh & Saratchandra 2012). Temperatures above 35ºC inhibit growth, which can sometimes cause death and reduce cocoon quality (Wongsorn et al. 2015). Inappropriate humidity causes stress on larvae and decreases feeding activity, so the growth and development of larvae are disrupted (Mulyani 2008). In the tropics, the larvae of the silkworm have a high-temperature tolerance of up to 30°C (Hailu et al. 2018). In this study, the average temperature at rearing site (27.9±0.9°C) and air humidity (85.7±2.15%) were ideal for the growth of 1^{st}-4^{st} instar larvae. Brahma (2015) reported temperature range 20-40ºC is suitable for the rearing of *S. ricini*. Water spraying during the day before feeding in the rearing site helps maintain humidity. Control of ventilation in the rearing site also is needed to maintain the air temperature and humidity (Atmosoedarjo et al. 2000).

Food serves as the main energy source for livestock for growth and reproduction (Marhamah et al. 2019). Andadari et al. (2013) reported the hatched *Bombyx mori* silkworms to have a low water content (75-78%) and a high-water content is needed for 1^{st} and 2^{nd} instar larvae. In addition, the small caterpillar (1^{st} to 3^{rd} instars requires more protein and carbohydrates for growth. Feed consumption increased significantly in the 4^{th} to 5^{th} instars larvae. The newly hatched larvae had an average length of 3-4 mm. Bongale & Chaluvachari (1993) also stated that the leaves nutrient content, i.e., water content, total protein, carbohydrates, and minerals, affects the growth of *Bombyx mori* silkworms.

In this study, the length and weight of 5^{th} instar was highest in larvae fed *by M. glaziovii* and the lowest occurred in *T. cattappa*. The weight of the 5^{th} instar is an important factor that determines the quality of cocoons and the formation of silk fibers (Estetika & Endrawati 2018). Samsijah & Kasumaputra (1975) reported that instar 3 needs more water and protein. On the other hand, 4^{th} to 5^{th} instar need more protein and carbohydrates to produce silk fiber. Caterpillars need two proteins, sericin and fibroin, while carbohydrates and fats are useful as energy sources and food reserves during the cocooning process. Atmosoedarjo et al. (2000) reported the weight of silk glands in 5^{th} instar, quickly increased to 40% of body weight with feed requirements are almost 90%. The increase in the weight of the silk gland is proportional to the body weight of the silkworm. The highest protein and carbohydrate contents in leaves of *M. glaziovii* in this study were highest (8.28% and 14.24, respectively) that promote the silkworm's growth. These results supported Kumar & Gangwar (2010) that the maximum body weight of larvae was fed by *M. glaziovii* (6.80-6.82 g). The nutrient digestibility also affects the growth that is characterized by a shorter rearing period of *S. ricini* (Sakthivel & Qadri 2017).

The leaves of *C. aconitifolius* result a low growth of the caterpillar and supposed that *C. aconitifolius* contains several active substances, such as tannins (72%), flavonoids (23.72%), and phytate (1.97%) that inhibit food digestion by decreasing protein digestibility (Obichi et al. 2015). *Terminalia cattappa* leaves also have a high tannin content (37.17%) (Dhora 2017). Based on the proximate test, the protein and carbohydrate content of *C. aconitifolius* were 5.79% and 12.77% affected the growth of the caterpillars.

A feed with different nutritional content impacts the growth of *S. ricini* silkworms (Dinata et al. 2019). Nutrients and water influence the quantity and quality of cocoons (Shifa et al. 2014). Larvae begin to cocoon at the end of the 5th instar. The cocooning process begin when the larvae stop eating and its body turned transparent since all the feces are expelled. The larvae secrete silk fibers to protect themselves as the cocoons grow. The cocoon formation process is completed in 1-3 days. The nature of cocoons is an important element of silkworm cultivation. The cocoon quality is influenced by several factors such as, feed nutrition, air temperature, humidity, disease suppression, and breeding conditions.

The best cocoon produced was from larvae fed with *M. glaziovii*. The difference in the cocoon size was influenced by feed consumption and the ability to store nutrients. The unsuitable environmental, silkworms use more energy to overcome these environmental conditions. As a result, growth is not optimal and produced are inferior cocoon. Variations in cocoon size can also be influenced by several factors, such as variety, a seasonal time of maintenance, and environmental conditions (Atmosoedarjo et al. 2000).

The cocoon weight is important in estimating the amount of raw silk produced. Whole cocoon weight is the cocoon weight includes the cocoon shell and floss, and pupae. The cocoon quality related to feed quality, temperature, and humidity as well as the ability of larvae (4th and 5th instars) to accumulate proteins to form silk fibers (Cholifah et al. 2012). A study showed the cocoon weight produced by larvae fed of *M. glaziovii* was comparable with *M. esculenta*. Similarly, Kumar and Gangwar (2010) reported silkworm fed by *M. glaziovii* produced higher yields (3.25 g).

The study showed the maximum load of fiber varied among treatments and the larger diameter of the single fiber showed the greater load. Fiber produced by larvae fed of *M. glaziovii* feed showed the highest average tensile strength (77.8 Mpa). On the other hand, the highest extensibility (23.9%) occurred in fiber produced by larvae fed of *C. aconitifolius*. The strength of the tensile seems related to the nutrient content in the leaf. The tensile strength of *S. ricini* in the current study was lower than fiber of *B. mori* (500-690 MPa) (Perez et al. 2000). Saroso and Darmono (2002) reported a silk fiber with a high extensibility produce a fine yarn. This study also showed the extensibility of silk fiber in larvae fed by *C. aconitifolius* (23.9%) and *T. cattappa* (22.1%) was higher than *B. mori* silk fiber (4-19%).

The female and male moths can be distinguished based on body size. The female has a larger body size than the male. The large body size of a female is related to fecundity and egg production, the large body size allow to lay eggs in greater numbers (Sober et al. 2019). The mating phase of *S. ricini* begins with the female tries to attract the male by protruding its abdomen and releasing pheromones. The male responds to this behavior by flying toward the female (Gillot 2005). In addition to pheromones, visual and auditory stimuli are also used in this phase. This study showed that the longest calling was 5.03 minutes. The next step of mating behavior is copulation. Gillott (2005) stated the most important factor in the copulation process is the physiological state of the female. The valve of the male clasper touches and attaches to the abdomen at the tip of the female. After copulation, the female tends to avoid the male for a long time due to the presence of sperm in the spermatheca. The longest copulation duration in this study was 926 minutes. The female then look for a potential location for laying the eggs (Steidle & van Loon 2002). This study showed the eggs laid by the female ranged from 66 to 290. The number of eggs laid by female is influenced by several factors, including nutrition and environmental factors, such as temperature, light, and humidity (Hans & Sundaramoorthy 2003).

CONCLUSION

The best growth of *S. ricini* larvae measured by larval length and weight were fed by *M. glaziovii*. The larvae fed by *M. glaziovii* also produced the largest cocoon size with high fiber quality. The female moth has a larger body size than the male. The larval feeding types did not affect the mating duration and imago characteristics.

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The authors declare that they have no conflict of interest.

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No ethical issue required for this research.

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My manuscript has no associated data.

Authors' Contributions
RMT designed, performed experiments, and wrote the manjuscript; TAW, WPP, YCE designed of the research, data analysis, and revision of the manuscript. All authors read and approved the final manuscript.

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