INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
24–0304/2024/32–6–633–638
DOI: 10.17957/IJAB/15.2246
http://www.fspublishers.org

Full Length Article

Effect of Cleaning Frequency of Silkworm Rearing Sites on Silkworm Durability and Cocoon Quality

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Received 04 July 2024; Accepted 01 September 2024; Published 07 November 2024

Abstract

Production of silk thread (*Bombyx mori* L.) in Indonesia, especially in South Sulawesi, is declining. Therefore, the aim of this was to increase silkworm production by looking at the effect of the frequency of cleaning of rearing areas on silkworm durability and cocoon quality. This research was conducted at the Social Forestry and Environmental Partnership Center, South Sulawesi, Indonesia. Data analysis used one-way ANOVA, and if there were differences in the effect of treatment, a further Duncan test was carried out. The second analysis used was Principal Component Analysis (PCA) using XLSTAT. The results showed that the best treatment for the durability of young silkworms was treatment C (78.42%). In comparison, for mature silkworms the best treatment was 86.27% in treatment D. The best cocoon quality for the percentage of defective cocoons 2.67% was in treatment A. Weight of the cocoon was the highest (1.46 g) in treatment D and the best percentage of cocoon shell (16.18%) was in treatment B. PCA analysis showed a close relationship between the percentage of defective cocoons and the weight of the cocoons. The results also showed that treatments A and B had the same effect on silkworm survival and cocoon quality. This research provided information for farmers who are cleaning the place where silkworms are to order to increase silk production.

Keywords: Cocoon harvesting; Hygiene; Rearing; Productivity; Sericulture

Introduction

The development of natural silk in Indonesia began in 1950 (Tenriawaru *et al*. 2021). Silk thread production in Indonesia has decreased over time (Fambayun *et al*. 2022). Until now, silk thread production in Indonesia, especially in South Sulawesi, has experienced a decline. Maintenance and cleanliness of the production site are some of the influences on silkworm production (Tayal and Chauhan 2017).

Silkworms are insects that produce silk threads whose life cycle undergoes complete metamorphosis. The growth of silkworms is greatly influenced by the climatic conditions at the rearing location (Saikia *et al*. 2016). Silkworms are kept in one place, which allows dirt, food scraps, and silkworms to become one. Cleaning the place where silkworms are kept is carried out when the place has seen food waste that has accumulated (Barcelos *et al*. 2021).

Cleaning the place is followed by expanding the place and the size of the silkworms. Food and hygiene must be considered when carrying out silkworm-rearing activities. Mulberry leaves are given as food for silkworms (Qin *et al*. 2020). Silkworm droppings, leaf debris, and dead silkworms can disrupt the physiological state of silkworms. After the silkworm hatch, the rearing area with the remains of mulberry shoots, silkworm droppings, and other rubbish must be cleaned. Cleaning the rearing area is carried out to prevent the silkworms from contracting disease (Chopade *et al*. 2021). Cleaning the silkworm breeding area occurs when the rearing area shows dirt and food waste (Manjunath *et al*. 2020). Cleaning the place can also be followed by expanding the place, because as the size of the silkworms increases, a more prominent place is needed.

The durability of silkworms depends on the place's maintenance process and cleanliness. The cleanliness of the silkworm rearing area can influence the silkworms' durability. Cleaning of the rearing area must remain controlled, and continuous interaction with silkworms must be considered. Excessive interaction can disrupt silkworm activity (Si *et al*. 2021). When entering the cocoon phase, the silkworms are immediately moved to the cocoon area so that the cocoons produced can form properly.

Cocoons are important globally, not only in textile production but also in many industries and ecosystems. Silkworm cocoons, mainly used to produce silk, are an integral part of the textile industry, making a considerable contribution every year and supporting livelihoods in many

To cite this paper: Sadapotto A, A Prastiyo, S Nuraeni, M Irfan (2024). Effect of cleaning frequency of silkworm rearing sites on silkworm durability and cocoon quality. *Intl J Agric Biol* 32:633–638

countries, especially Asia. Apart from textiles, cocoons are also used in traditional medicine and biotechnological applications due to their unique properties (Pugina and Caiut 2021). Additionally, cultivating silkworms supports sustainable agricultural practices, as silkworms are often grown on mulberry plantations, contributing to the local economy and increasing biodiversity. Therefore, the impact of cocoons on economic, ecological, and cultural dimensions, thus underscoring their global significance (Li *et al*. 2023).

The result of raising silkworms is cocoons. The cocoons are further processed into thread and cloth. Therefore, to obtain quality silk thread, several factors influence the quality of the cocoon, namely, conditions during maintenance, including cleaning the silkworm rearing area and the cocoon process (Mallikarjuna and Balasaraswathi 2023).

Silkworms have cocoon quality standards ranging from the best class A to low-class D. Class C cocoon quality is a category that reflects medium standards in the processing and selection of silk fibers. Class C cocoons typically indicate fibers with minor defects or imperfections, such as uneven color or a slightly rough texture. Class C cocoons can still produce good-quality fabric and are used in various products, including clothing and accessories (Nuraeni *et al.* 2021). This quality balances price and performance, making it an economical choice.

The type of silkworm used was the parent silkworm type PBE. Based on this, this research aims to analyze the effect of the frequency of cleaning of rearing areas on the durability of silkworms and the quality of cocoons. This research will likely inform farmers about the development and increase of silkworm production.

Materials and Methods

Preparation for rearing silkworms

The rearing process is carried out by taking the silkworm eggs from the incubator, soaking them in a 2% formalin solution and water in a ratio of 3:1 and then drying them in the sun. Heated the HCl solution to a temperature of 48°C, soaked the egg paper in the HCl solution for 5 min and then put it in water for 15 min. The eggs are then dried and stored in the incubation room. After the eggs were stored for five days, the silkworm eggs were wrapped in paraffin paper. The steps taken in this cleaning were in the 1^{st}, cleaning was carried out when there was a lot of leftover feed. Cleaning was done by placing a net over the silkworm area. Leaves were placed on the net and then wait until the silkworms climb onto the net. The net and mulberry leaves are transferred to another sasag. The rafters underneath were cleaned or replaced. After the sasag is clean, the silkworms and mulberry leaves were placed back on the sasag.

Incubation of silkworm eggs

Egg were incubated for hatching in a room where temperature, humidity and light can be regulated so that silkworm eggs can hatch properly and evenly at the planned time. This was done up to two days before hatching. According to Nunuh and Andikarya (2006), the way to carry out incubation was to spread silkworm eggs evenly in a hatching box, covered them with paraffin paper, stored in a cool place protected from direct sunlight, set the temperature to 25°C, humidity 75-80%, with a light setting of 18 h, of light and 6 h, of darkness every day until two days before hatching time. The room was kept entirely dark, by closing the curtains and turning off the room lights in the hope that the eggs can hatch simultaneously.

Cleaning treatment for silkworm-rearing areas

Each experimental treatment was repeated three times. The experimental design used was a randomized block design consisting of 4 treatments, namely (A) cleaned five times during maintenance, namely instar 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th}; (B) cleaning three times during maintenance, namely instar 1^{st}, 3^{rd} and 5^{th}; (C) cleaning once during maintenance, namely in instar 3^{rd} and (D) daily cleaning for 12 days in the maintenance cycle.

Silkworm durability

The durability of silkworms is important to see their adaptation to environmental conditions. Environmental conditions greatly influence the resistance of silkworms (Li *et al*. 2016). The following expression was used to know the percentage of durability of youngor instar 1^{st}–3^{nd} silkworms (DK) was measured with the equation:

$$DK = \frac{N3}{Ns} \; x \; 100\%$$

Where N3 is numberof third instar silkworms and NS is number of eggs hatched.

Likewise, the durability of mature or instar 4–5^{th} silkworms (DB) was determined with the equation:

$$DB = \frac{Nm}{N5} \; x \; 100\%$$

Where Nm is number of cocoon silkworms and N5 is number of early instar 5^{th} silkworms.

Cocoon quality

The quality of silkworm cocoons is very important for supporting the silk thread produced. Good quality silk thread is made from good cocoons (Khordadi *et al*. 2024). The quality of cocoons was divided into the percentage of defective cocoons, the number of cocoons, percentage of cocoon shells (KC) with the equation:

$$KC = \frac{Nc}{Nm} \; x \; 100\%$$

Where Nc is number of defective cocoons and Nm is the number of cocoon silkworms.

Similarly, the cocoon shell (KK) was determined with the expression:

$$KK = \frac{Wtp}{Ws} \; x \; 100\%$$

Where Wtp is weight of cocoons without pupae and Ws is weight of fresh cocoons.

Indonesia has set cocoon quality standards, and classifies is according to SNI (2011): 7635 (Table 1). The quality of the cocoon determines the quality of the silk thread that will be produced (Sobirov *et al*. 2021).

Data analysis

The research data were analyzed for one-way ANOVA using the SPSS 29.0 tool. Three replications were used in each treatment. The treatments showing significant differences were compared using Tuckey test. Principal Component Analysis (PCA) was performed using XLSTAT version 2021.2.2.

Results

Durability of silkworms

The highest percentage of young silkworm survival was produced by treatment C, with an average of 78.42% and the lowest was treatment B, with an average of 66.55%. The analysis results showed that treatments did not have a significant effect. The highest durability of mature silkworm was produced by treatment D, with an average of 86.27%, and the lowest was treatment A, with an average of 72.12%. The analysis results showed a significant effect on the treatment. The resistance of young silkworms is different from that of mature silkworms (Table 2).

Quality of silkworm cocoons

The lowest percentage of defective cocoons was treatment B, namely cleaning three times during rearing, with an average of 5.77%, and the highest was produced by treatment C, with an average of 17.22%. The analysis results did not significantly affect treatment. The highest cocoon weight was produced by treatment D, with an average of 1.46 g, and the lowest in treatment B, with a weight of 1.37 g. The analysis results did not significantly affect each treatment. The highest percentage of cocoon shells was noted in treatment B, with an average of 16.18%, and the lowest was in treatment C, with an average of 14.94%. The analysis results showed a similar treatment effect (Table 3).

Effect of cleaning treatment on silkworm rearing sites

The results of the PCA analysis showed a close relationship between several variables of silkworm endurance and cocoon quality (Fig. 1). The dendrogram image shows the closeness between the percentage of defective cocoons and the weight of the cocoons and, conversely, the resistance of young silkworms with cocoon shells that are far from each other.

Table 1: Cocoon quality classification requirements (SNI 7635:2011)

Class	Deformed cocoon (%)	Cocoon weight (g)	Cocoon shell (%)
A	≤ 2.0	≥ 2.0	≥ 23.0
B	2.0–5.0	1.7–2.0	20.0–23.0
C	50–8.0	1.3–1.7	17.0–20.0
D	≥ 8.0	≤ 1.3	≤ 17.0

Table 2: Durability of silkworms

Durability of silkworms	Treatment			
	A	B	C	D
Young silkworm (%)	67.50	66.55	78.42	70.08
Mature silkworm (%)*	72.12a	70.29a	81.26b	86.27b

Note: The sign (*) indicates that there is a significant at $P \leq 0.05$

Table 3: Quality of silkworm cocoons

Treatment	Deformed cocoon (%)	Cocoon weight (g)	Cocoon shell (%)	Class
A	2.67	1.44	15.54	C
B	2.80	1.37	16.18	C
C	2.79	1.40	14.94	C
D	3.25	1.46	15.31	C

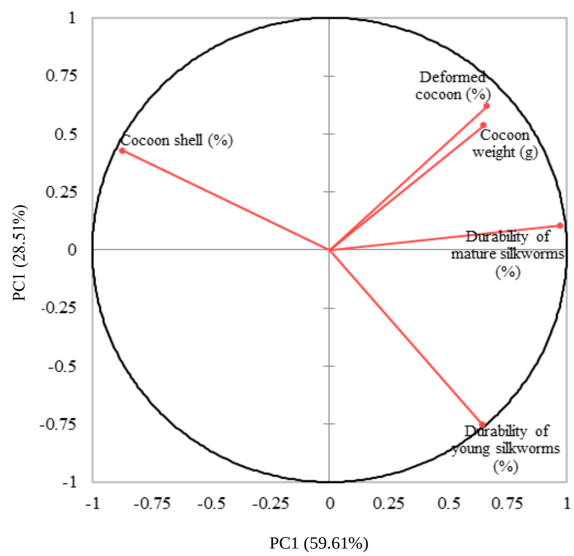

Fig. 1: Dendrogram of variable clustering

The results of the PCA analysis on the treatments (Fig. 2) show that treatments A and B have a similar effect, while treatments C and D have a significant difference. This aligns with the one-way ANOVA, which is presented by the resistance of mature silkworms.

Fig. 3 shows that several variables showed a relationship with treatment, as shown in the resistance of young silkworms, which is close to treatment C. The weight of cocoons and the percentage of defective cocoons are close to treatment D. This showed that several treatments significantly influence the variables.

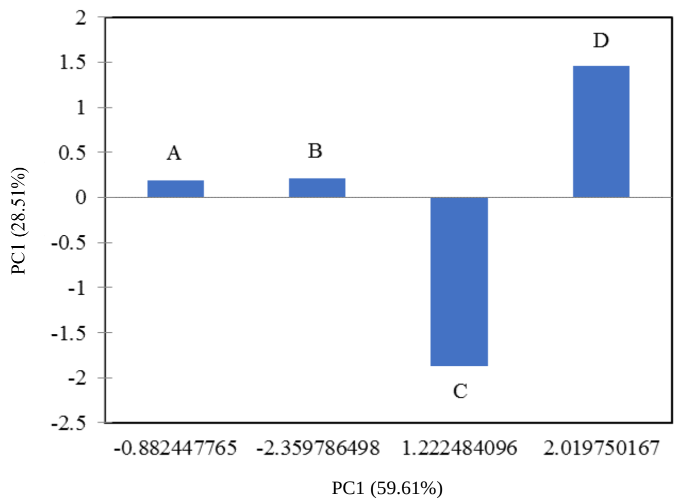

Fig. 2: Effect of treatment on silkworms

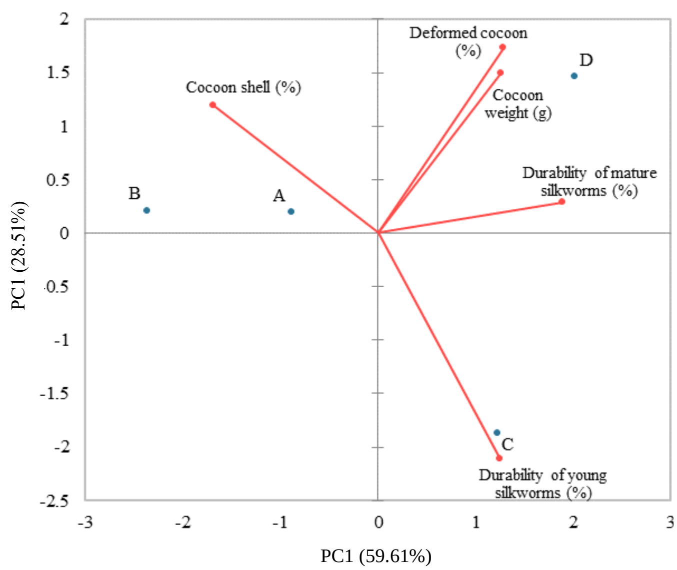

Fig. 3: PCA analysis, the relationship between treatment effects on silkworm survival and cocoon quality

Discussion

Cleaning frequency did not significantly affect fresh cocoon weight (P>5%). Average cocoon weight (Table 3) with daily cleaning (1.46 g), then cleaning five times during maintenance (1.44 g), then cleaning one time during maintenance (1.40 g), and the lowest three times cleaning during maintenance (1.37 g). Heavy larvae will produce cocoons with thick silk fibers (Nzyoki 2020). The cocoon weight will increase if the final body weight of the 5th larvae increases (Wani *et al.* 2018).

Cocoon classification based on the weight of the cocoons from the four treatments is included in class C. The weight of the cocoons depends on the type of silkworm and the conditions during rearing (Chieco *et al*. 2019). The highest was treatment B (cleaning three times during maintenance) compared to other treatments. Silkworm cocoon weight is greatly influenced by environmental conditions (Offord *et al*. 2016).

The classification of cocoon quality is based on the cocoon shell, and the average cocoon shell from the four treatments is included in class C. This is because the percentage of the cocoon shell is related to the cocoon and its shell's weight, so the average value of the cocoon shell produced by each treatment is higher (Zhao and Zhang 2020). The different cleaning frequencies of each treatment cause this. For all treatments in this study, the cocoon classification was based on defective cocoons, cocoon weight, and cocoon skin, which were included in class C.

There are several reasons why a cocoon becomes deformed. The outer stained cocoon occurs by silkworm feces when the silkworm defecates (Singh *et al.* 2023). Internally stained cocoons occur when the pupa dies or is injured inside (Prasobhkumar *et al*. 2019). Double cocoons often occur when the silkworms are too mature, the cocoons are too dense, the space for the silkworms to cocoon is narrow, the temperature is too high, the humidity is high, and the airflow is too strong at the start of cocooning (Chauhan and Tayal 2017). Thin-tipped cocoons are cocoons that are very thin at both ends. These cocoons are caused mainly by high temperatures during incubation, low temperatures with high humidity during rearing, and low temperatures and low humidity during cocooning (Jumaghulov and Rakhmanova 2023).

The type of mulberry leaf feed used in raising silkworms is *Morus alba*. A striking characteristic of the *Morus alba* mulberry leaves is that the stem segments are short, and the growth is predominantly lateral (Rahman and Islam 2021). This plant is around 1.5 m high with many branches. When the silkworms have molted, some leaves are not eaten. If these leaves are not eaten by the silkworms and left to continue accumulating, they will interfere with the growth of the silkworms. So that silkworm droppings and leftover leaves do not become a source of disease, they need to be cleaned. With the development of the silkworm, the silkworm's place must consistently be expanded. Expansion of premises must be carried out carefully and at the right time. The expansion of silkworms should only be done at a specific time to avoid losing many silkworms. If the silkworm cannot be expanded in one place, then move the silkworm to another place.

When cleaning the rearing area, you must be careful with silkworms because it will stress them, which can have fatal consequences, causing them to die as with other types of insects in general, both useful and pest insects are closely related to their living environment. Environmental changes can suppress, inhibit, or even stimulate the growth of insect populations without human intervention (Skendzic *et al.* 2021). The silkworm's adaptability and need for environmental temperature can also change (Guo *et al*. 2018). These changes are caused by changes in seasonal ecological conditions and the state of feeding in the silkworm's body.

Conclusion

The effect of cleaning treatment where silkworms were kept on the resistance of the silkworms did not significantly impact the resistance of young silkworms but had a significant effect on the resistance of mature silkworms. Cleaning the rearing area also did not significantly affect the cocoon quality. The best treatment for the resistance of young silkworms was treatment C, with a percentage of 78.42%, while for mature silkworms, treatment D with a percentage of 86.27%. The best treatment for cocoon quality for defective cocoons was in treatment A (2.67%), for cocoon weight, it was in treatment D with a weight of 1.46 g, and cocoon skin was in treatment B (16.18%).

Acknowledgments

Thanks to the Forest Protection and Insect Laboratory. Thanks also to the Bili-Bili Social Forestry and Environmental Partnership Center, Gowa Regency, South Sulawesi, Indonesia.

Author Contributions

AS and MI planned the experiments, AP and SN interpreted the results, AS, SN and MI made the write and AP statistically analyzed the data and made illustrations.

Conflicts of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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