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Race to Quality: A Study of Tasar Silkworm Cocoon Traits

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research work investigates the post-cocoon parameters of three Tasar silkworm races: Daba Bivoltine (DBV), Daba Trivoltine (DTV) and BDR-10, reared during the second crop, to enhance understanding of their qualitative and quantitative traits for commercial sericulture. Conducted at the Silk Technical Service Center (STSC) of Central Silk Technological Research Institute (CSTRI), Central Silk Board (CSB) in Bilaspur, Chhattisgarh, the study measured various parameters, including peduncle length, weight, thickness, cocoon color, shape, weight, shell weight, shell ratio, filament length, non-broken filament length (NBFL), filament denier, raw silk recovery, reelability,

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boil-off loss and the number of cocoons required to produce 1 kg of raw silk. The results revealed that BDR-10 exhibited the highest cocoon weight, reelability and raw silk recovery, making it the most productive race, while DBV showed superior filament length, shell weight and denier, providing a balance between productivity and quality. Although DTV demonstrated lower performance in some parameters, it exhibited the highest shell ratio and filament denier, indicating its potential for specific applications requiring thicker filaments. The study concludes that BDR-10 is the most promising race for maximizing silk yield and quality, DBV offers a balanced option, and DTV can still be utilized for commercial reeling with appropriate precautions.

Keywords: Tasar silkworm; post-cocoon parameters; DBV; DTV; BDR-10; sericulture; silk production.

1. INTRODUCTION

Sericulture, the art and science of silk production, involves cultivating host plants, rearing silkworms, harvesting their cocoons and transforming these ethereal fibers into exquisite textiles. This craft, steeped in tradition and passed down through generations, continually evolves in response to technological advancements, market demands and environmental considerations. Raw silk is composed of two proteins: fibroin, a fibrous protein, and sericin, a globular protein. Sericin acts as a gum, coating fibroin and binding it together within and across layers. There are four varieties of silk available worldwide: Mulberry, Eri, Tasar and Muga Silk, categorized into two groups: Domesticated Silk and Wild (Vanya) Silk. Mulberry Silk is domesticated, while the other three are wild, as they are reared in open environmental conditions. India is the only country producing all four varieties of silk.

Tasar silk has two sub-varieties based on geographical conditions: Tropical Tasar and Temperate Tasar. Tropical Tasar is found in tropical regions, whereas Temperate Tasar is found in colder regions. In India, tropical Tasar cocoons are mainly produced in Jharkhand, Chhattisgarh and Odisha, with smaller proportions produced in Maharashtra, Andhra Pradesh, Telangana, Bihar, Madhya Pradesh, West Bengal and Uttar Pradesh. Tasar sericulture has been practiced in India for over 1,000 years and is a significant source of income and livelihood for the tribal population. Tribal people rear Tasar silkworms and produce cocoons, which are then converted into yarn by rural people, providing them with income and livelihood opportunities. Tasar sericulture supports ecological balance by conserving and planting more host plants. Numerous studies on tasar silkworm importance for the tribals welfare were discussed by Vishaka et al. (2019), Nadaf et al. (2019), Selvaraj et al. (2020), Chandrashekharaiah et al. (2022A), Reddy et al. (2021), Chandrashekharaiah et al. (2022B), Vishaka et al. (2020), Vishaka et al. (2022), Nadaf et al. (2021)**,** Vishaka et al. (2021), Nadaf et al. (2022A), Nadaf et al. (2022B), Rathore et al. (2022), Dansana et al. (2024).

Among the notable initiatives in Tasar sericulture, the Bhagamunda Tasar Silk Park in Kendujhar, Odisha, stands out. Established in 1978 and evolved into a full-fledged park in 2019, the initiative aims to improve the livelihoods of tribal women through skill development and financial independence. The park's activities include block plantations, sourcing silkworm seeds, marketing strategies and capacity building. The study by *Behera et al. (2023)* indicates a significant enhancement in the living standards and financial stability of the beneficiaries, including rearers, seed rearers, private graineurs and reelers. *Swain et al. (2023)* evaluated the performance of pilot project centers in Sundargarh, focusing on the tasar silk. The study highlighted the contribution of these centers to the local economy, providing insights into the impact of various initiatives on production and income levels. *Dansana et al. (2024)* focused on the role of Vana Samrakshana Samiti (VSS) in the economic empowerment of tasar sericulturists in Nabarangpur and provided an analysis of the socio-economic impact of VSS initiatives, highlighting improvements in income, living standards, and community participation. It underscored the importance of sustainable practices and community involvement in promoting the growth of tasar sericulture in the region.

Tasar silk cocoons are formed by the silkworm *Antheraea mylitta D.*, which primarily feeds on the leaves of *Terminalia arjuna* (Arjun), *Terminalia tomentosa* (Asan), and *Shorea robusta* (Sal). Among the 44 ecoraces of Tasar silkworms found in India, Daba is predominantly cultivated race. From a commercial perspective, it is essential to study and analyze the post-

cocoon parameters of Daba and BDR-10, an authorized race.

The primary difference between Daba Bivoltine (DBV), Daba Trivoltine (DTV) and BDR-10 Tasar Silkworm lies in the generations or biological cycles these silkworms complete in a year. The DBV and BDR-10 silkworms complete two lifecycles per year, while the DTV silkworm completes three. The quality of the cocoon and silk produced by these silkworms varies, which this study aims to understand. The following post-cocoon parameters were examined and compared: Peduncle Length, Peduncle Thickness, Peduncle Weight, Cocoon Color, Cocoon Shape, Cocoon Weight, Shell Weight, Shell Ratio, Filament Length, Filament Denier, Non-Broken Filament Length (NBFL), Raw Silk Recovery, Reelability, Boil Off Loss, and the number of Cocoons Required to Produce 1 Kg of Raw Silk.

This study aims to provide a comprehensive analysis of the post-cocoon parameters of DBV, DTV, and BDR-10 Tasar Silkworm races, contributing to the understanding of their qualitative and quantitative traits and their implications for commercial sericulture.

2. MATERIALS AND METHODS

The study was conducted at Central Silk Board-Silk Technical Service Centre-CSTRI, Ministry of Textiles, Government of India, Bilaspur, Chhattisgarh (22.09°N 82.15°E, above mean sea level 207m). The materials used and the methods adopted during the study are detailed in this chapter.

Tasar silkworm races selected for the study:

1. Daba Bivoltine (DBV), II crop
2. BDR-10, II crop
3. Daba Trivoltine (DTV), II crop

Study Period: 2024

Collection of Tasar Cocoons: DBV and DTV second crop cocoons were collected randomly from grainage house of Basic Seed Multiplication and Training Center (BSMTC), Basic Tasar Silkworm Seed Organisation (BTSSO), Bastar, Chhattisgarh while BDR-10 second crop cocoons were randomly collected from the grainage houses of BSMTC, Boidadar, Chhattisgarh.

Around 200 Coccons of each races were brought to CSB –STSC, Bialspur where it was divided in 3 parts i.e. 20 cocoons for Shell Ratio, 20 Cocoons for single filament assessment and rest 160 cocoons for reeling performance test.

Recording of Morphometric parameters: The first group of twenty cocoons of all the three races were visually inspected for color and shape of the cocoons. The peduncle was cut off from the cocoons and the length, thickness and weight of the each peduncle was recorded. The length was measured using measuring scale, thickness by using vernier calliper and weight by using electronic weighing balance.

Each out of twenty cocoons of all the races were tested for single cocoon weight. The weight of individual cocoons was recorded using an electronic weighing balance after cutting off the peduncle.

The above said twenty cocoons were cut with the help of cutter to remove the pupa. After removing pupa, the weight of individual whole empty shell and pupa were recorded separately using electronic weighing balance.

Shell Ratio (%): It is the ratio of cocoon shell weight with respect to Green cocoon weight. It is important parameters which gives an idea about the available silk content in cocoon with respect to cocoon weight.

$$\text{Shell Ratio (\%)} = \frac{\text{Empty Cocoon Shell Weight x 100}}{\text{Green Cocoon weight}}$$

Boil off Loss (%): It is the loss of cocoon shell weight during the cooking process mainly due to dissolution of sericin in cooking bath.

> Boil off Loss (%) = (Shell weight before cooking- Shell weight after cooking) x 100 / Shell weight before cooking

The twenty cocoons of first group which were already cut were taken with cocoons of second group for cooking in the same bath for the same time. After cooking the said cut cocoon shells were left to dry completely. The weight of these dried cocoon shells was recorded using electronic balance. Then by applying above formula the boil off loss (%) was calculated for all three race cocoons.

Single Cocoon Filament Assessment: The second group of twenty cocoons were tested for Filament Length, NBFL (Non Broken Filament Length) and Filament Denier. To test these

parameters the cocoon were cooked using CSTRI Tasar Plus cooking method. The cocoon were collected in a net cloth and tied after that it was boiled for 30 minutes in a bath containing 6 g/l washing soda and 5 g/l baking soda with closed lid. After boiling the cocoons were given steam for 25 minutes in the same bath by keeping it on a stand above the water level. After cooking the cocoons were taken out and left to cool down and deflossed individually. After deflossing individual cocoons filaments were reeled on Epprouvette machine where the number of revolutions and number of breaks were recorded for individual cocoon. After the complete unwinding of the filament from cocoons, the wound filament layer was removed and kept for drying. The weight of this filament was recorded using electronic weighing balance and the following parameters were calculated using below formulas.

Filament Length: It is the total length of silk filament in the cocoon shell which was reeled on Epprouvette machine. The circumference of machine is 1.125 meters. The filament length determines the workload, rate of production, evenness of the silk thread and the dynamo metric properties of the output.

$$\text{Filament Length} = \text{Total Number of Revolutions x } 1.125 \text{ m}$$

NBFL: The Non Broken Filament Length is the length of silk filament obtained from the cocoon without any break. It is also very important parameter which determines the reeling speed, efficiency & productivity of the process.

$$\text{NBFL} = \frac{\text{Filament Length}}{1 + \text{ number of breaks}}$$

Filament Denier: It measures the fineness and coarseness of silk filament obtained from cocoon. It is defined as the weight of 9000 meter long filament in grams. It decides the limitation of fineness of yarn that can be produced from a particular filament as yarn denier limit depend upon the individual filament denier. Lesser is the denier finer will be the filament.

$$\text{Denier} = \frac{\text{Weight of the filament (in gm) x } 9000}{\text{Length of Filament (in meters)}}$$

Reeling Performance: The third group of 160 cocoons were taken for cooking after cutting off the peduncle. The cocoons were cooked using CSTRI Tasar Plus cooking method for dry reeling. After cooking, individual cocoons were deflossed and the reeling performance was tested on Buniyad Reeling machine. Where 8 cocoons filament were reeled together into yarn form. Number of breakages were observed and recorded manually. The deflossing waste, pelade waste and the yarn formed kept separately. All these were weighed using electronic weighing balance after drying. Various parameters as mentioned below were calculated with these data.

Raw Silk Recovery (%): It is the net amount of silk reeled out of the cocoon shell excluding the invisible losses in cooking and reeling process. The cocoon shells cannot be reeled completely as the top layer during deflossing i.e. in finding true end goes in waste and bottom layer which too fine also goes in waste as pelade waste.

Raw silk recover (%) = Weight of the yarn x 100 / Weight of the yarn + weight of the waste

Reelability (%): It is the ease with which the filament can be reeled out of cocoons. It depends upon the no. of breaks during reeling. Higher the breaks lower will be the reelability.

$$\text{Reelability} = \frac{\text{Total No. of Cocoons taken for reeling x } 100}{\text{Total No. of casting}}$$

Total no. of casting = No. of cocoons taken + No. of breaks

No. of Cocoons required to produce 1 kg of raw silk: It is the measure of the productivity of cocoons which depends upon many factors like shell weight, Boil off loss, filament length, NBFL, reelability and raw silk recovery.

No. of cocoons required for 1 kg raw silk = No. of cocoons taken x 1000 / Weight of Raw Silk produced (in g)

3. RESULTS AND DISCUSSION

While an earlier study by *Reddy et al. (2024)* assessed the reeling parameters of cultivated and wild tasar raily eco-race cocoons, the present study provides a detailed comparative analysis of cocoon parameters for three different races reared during the second crop: II DBV, II DTV, and II BDR-10. The parameters evaluated include peduncle length, weight and thickness, cocoon color and shape, cocoon weight, pupal

weight, shell weight, shell ratio, filament length, non-broken filament length (NBFL), filament denier, raw silk recovery, reelability, boil off loss and the number of cocoons required to produce 1 kg of raw silk. The results are tabulated and discussed in detail Table 1.

3.1 Peduncle Length

The peduncle length was longest in BDR-10, measuring 5.32 cm, indicating a robust and potentially more resilient structure for supporting the cocoon. DTV followed with a peduncle length of 4.66 cm, suggesting a moderately strong structure, while II DBV had the shortest peduncle length at 4.39 cm, which, although shorter, may still be sufficient for effective support of the cocoon. The present observation of the longest peduncle length in BDR-10 is consistent with the findings of *Vishaka et al. (2024)*, who reported that among the three eco-races, the length of cocoons with peduncle (CL+P) was highest in BDR-10 female cocoons (9.4 ± 0.988), followed by DBV (8.62 ± 0.397) and DTV (8.24 ± 0.825).

3.2 Peduncle Weight

BDR-10 exhibited the highest peduncle weight at 0.29 gm, potentially contributing to better anchorage and support of the cocoon. In comparison, DBV had a moderate peduncle weight of 0.18 gm and DTV had a slightly lower weight of 0.17 gm, which might suggest a lighter support structure.

3.3 Peduncle Thickness

Regarding peduncle thickness, DTV had the thickest peduncle at 1.92 mm. DBV followed with a thickness of 1.8 mm, showing a slightly less robust structure compared to II DTV. The thinnest peduncle was found in II BDR-10 at 1.72 mm, although still providing adequate support.

3.4 Cocoon Color and Shape

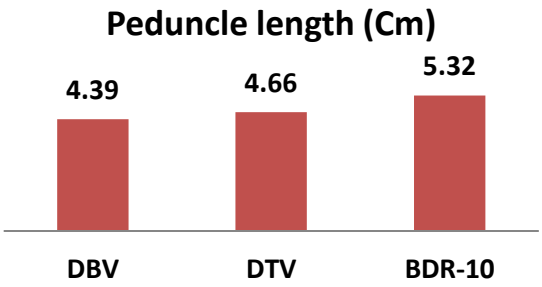
All three races produced cocoons that were brown and white in color, with an oval shape. This consistency in color and shape suggests a standard morphological trait across these races, indicating no significant variation in these particular characteristics among the races studied.

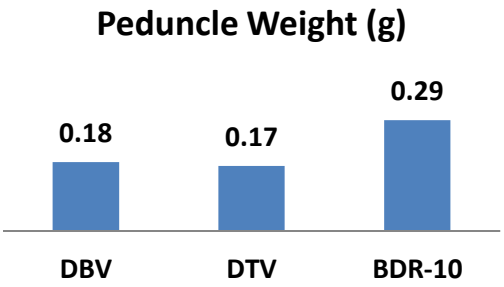
3.5 Cocoon Weight

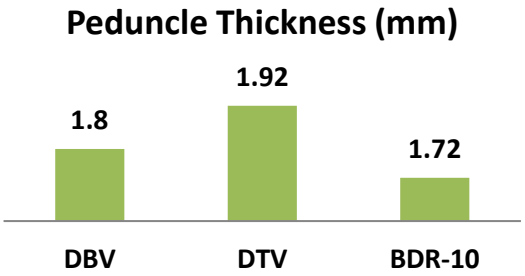
BDR-10 had the heaviest cocoons with an average weight of 12.85 gm, which is often associated with better silk yield. DBV also showed substantial cocoon weight at 12.45 gm, indicating good potential for silk production. The lightest cocoons were observed in DTV at 10.93 gm, suggesting a lower silk yield compared to the other two races. The same pattern was observed in the findings of Vishaka et al. (2024).

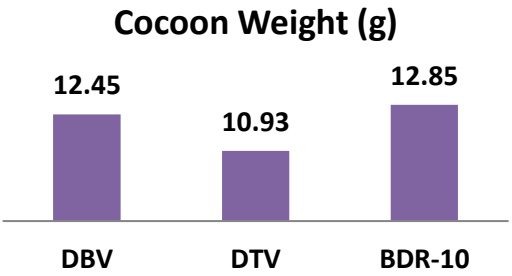
Table 1. Comparison of cocoon parameters of different races of tasar silkworm

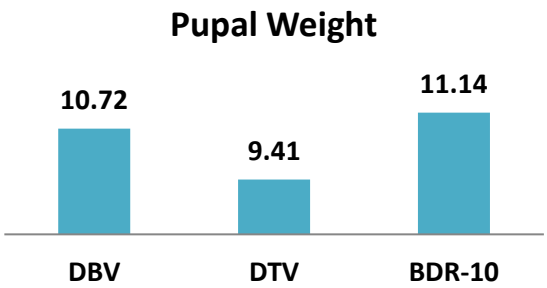
Sl. No.	Parameter	Unit	DBV	BDR-10	DTV
1	Peduncle Length	cm	4.39	5.32	4.66
2	Peduncle Weight	g	0.18	0.29	0.17
3	Peduncle Thickness	mm	1.8	1.72	1.92
4	Cocoon Colour	-	Brown White	Brown White	Brown White
5	Cocoon Shape	-	Oval	Oval	Oval
6	Cocoon Weight	g	12.45	12.85	10.93
7	Pupal Weight	g	10.72	11.14	9.41
8	Shell Weight	g	1.73	1.71	1.52
9	Shell Ratio	%	13.89	13.3	13.93
10	Filament Length	m	870.74	792.5	727.5
11	NBFL	m	142.15	165.91	133.59
12	Filament Denier	-	9.61	9.71	9.98
13	Raw Silk Recovery	%	62.14	64.84	51.11
14	Reelability	%	32.03	36.65	32.67
15	Boil Off Loss	%	11.1	11.38	15.37
16	No. of Cocoons (1 kg raw silk)	-	1111	1049	1451

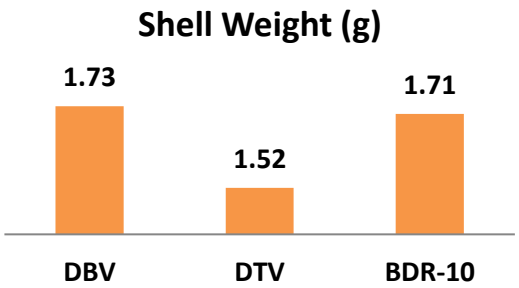

Peduncle length (Cm)
4.39
4.66
5.32
DBV
DTV
BDR-10

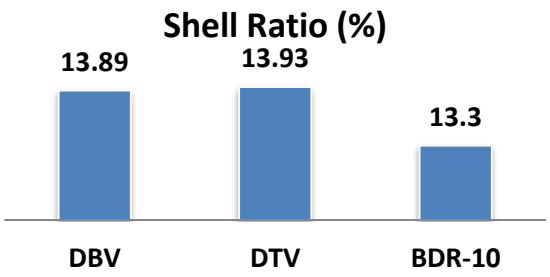

Peduncle Weight (g)
0.18
0.17
0.29
DBV
DTV
BDR-10

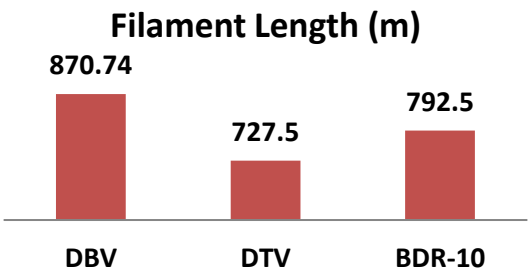

Peduncle Thickness (mm)
1.8
1.92
1.72
DBV
DTV
BDR-10

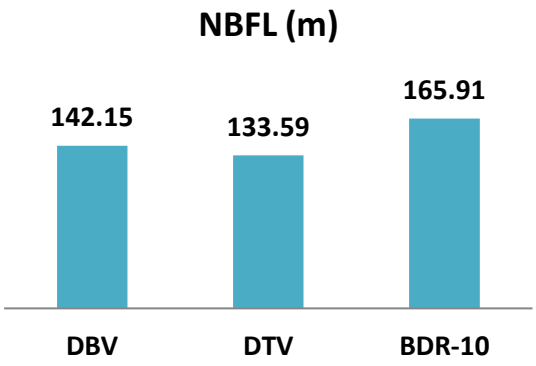

Cocoon Weight (g)
12.45
10.93
12.85
DBV
DTV
BDR-10

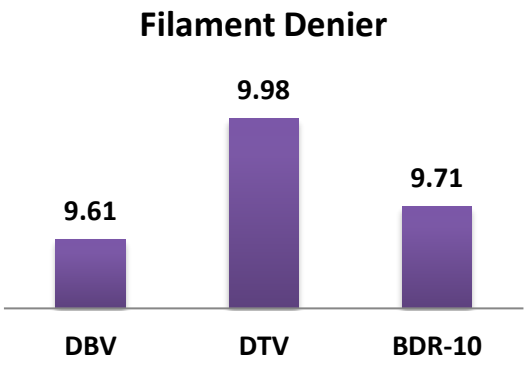

Pupal Weight
10.72
9.41
11.14
DBV
DTV
BDR-10


Shell Weight (g)
1.73
1.52
1.71
DBV
DTV
BDR-10


Shell Ratio (%)
13.89
13.93
13.3
DBV
DTV
BDR-10


Filament Length (m)
870.74
727.5
792.5
DBV
DTV
BDR-10


NBFL (m)
142.15
133.59
165.91
DBV
DTV
BDR-10


Filament Denier
9.61
9.98
9.71
DBV
DTV
BDR-10

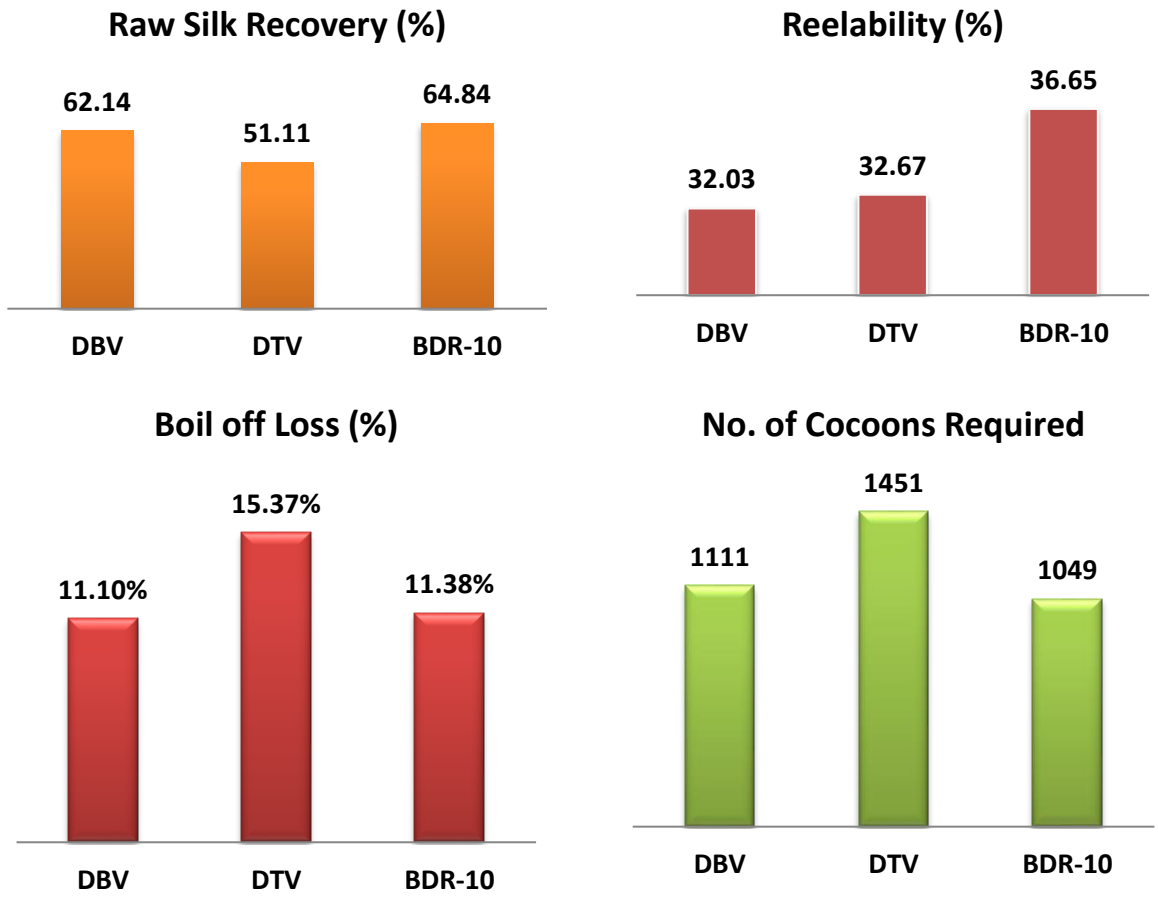


Fig. 1. Comparison of Cocoon Parameters of Different Races of Tasar Silkworm

3.6 Pupal Weight

The pupal weight was highest in BDR-10 at 11.14 gm, indicating a larger pupal size. II DBV followed closely with a pupal weight of 10.72 gm. The lowest pupal weight was found in II DTV at 9.41 gm, suggesting a smaller pupa and potentially less silk production.

3.7 Shell Weight

DBV had the highest shell weight at 1.73 gm, which generally correlates with better silk output. BDR-10 followed closely with a shell weight of 1.71 gm. The lowest shell weight was observed in DTV at 1.52 gm, indicating less silk material compared to the other races.

3.8 Shell Ratio

The shell ratio, which indicates the proportion of silk-producing material relative to the cocoon's total weight, was highest in DTV at 13.93%. DBV had a shell ratio of 13.89%, while BDR-10 had the lowest shell ratio at 13.3%.

3.9 Filament Length

The longest filament length was found in DBV at 870.74 meters, which is desirable for producing silk threads. BDR-10 had a filament length of 792.5 meters, while the shortest filament length was observed in DTV at 727.5 meters, indicating a lower potential for thread production.

3.10 Non-Broken Filament Length (NBFL)

BDR-10 exhibited the highest non-broken filament length (NBFL) at 165.91 meters, indicating a better quality filament with fewer breaks. DBV followed with a NBFL of 142.15 meters, while the lowest NBFL was found in DTV at 133.59 meters, suggesting more frequent breaks in the filament during reeling.

3.11 Filament Denier

The highest filament denier, which indicates the thickness of the filaments, was recorded in DTV at 9.98. BDR-10 had a denier of 9.71 and the lowest denier was observed in DBV at 9.61, indicating finer filaments, which are generally more desirable for fine-quality silk yarn.

3.12 Raw Silk Recovery

Raw silk recovery, which measures the yield of silk from the cocoon shell, was highest in BDR-10 at 64.84%, indicating a high yield. DBV followed with a recovery rate of 62.14%. The lowest recovery rate was observed in DTV at 51.11%, suggesting less efficient silk production.

3.13 Reelability

Reelability, which measures the ease of being reeled during reeling process, was highest in BDR-10 at 36.65%. DTV had a reelability of 32.67%, and the lowest reelability was observed in DBV at 32.03%, indicating comparatively less easy reeling than BDR-10.

3.14 Boil off Loss

Boil off loss, which indicates the loss of material during processing, was highest in DTV at 15.37%, indicating a higher loss of material. BDR-10 had a boil off loss of 11.38%, while DBV had the lowest boil off loss at 11.10%, indicating better material retention during processing.

3.15 Number of Cocoons

The efficiency in silk production was highest for BDR-10, requiring the least number of cocoons (1049) to produce 1 kg of raw silk. II DBV required 1111 cocoons to produce the same amount of silk. II DTV was the least efficient, requiring 1451 cocoons for 1 kg of raw silk, indicating a lower efficiency in silk production.

The comparative analysis of cocoon and post cocoon parameters of the three races provides valuable insights into their respective performances and potential for silk production. BDR-10 generally performed better in terms of cocoon weight, filament length, NBFL, raw silk recovery, and reelability, indicating its superior potential for high-quality silk production. DBV also showed strong performance in filament length and silk recovery, making it a viable option for silk producers. In contrast, DTV lagged behind in several parameters, although it exhibited the highest filament denier and boil off loss. II BDR-10 appears to be the most promising race for maximizing silk yield and quality, while II DBV offers a good balance of desirable traits. DTV, despite its lower performance in certain areas, may still be suitable for specific applications where thicker filaments are required. This comprehensive analysis serves as a foundation for making informed decisions in sericulture practices and enhancing the efficiency and quality of silk production.

4. CONCLUSION

The post cocoon parameters for any race of silkworm are very important from commercial and economical point of view as these parameters decide the productivity, economics, profitability and commercial viability of the reeling process (extraction of silk filament from cocoon). In this study the comparison of the post cocoon parameters gives an insight about the quantitative and qualitative parameters of DBV, DTV and BDR-10 cocoons. The quantitative parameters like cocoon weight, shell weight, filament length gives the idea about the quantity of silk available in the cocoon. Whereas qualitative parameters like NBFL, reelability and boil off loss indicates how much silk filament can be reeled out of available silk content with ease.

The study shows that only higher cocoon weight does not guarantee higher silk content which was observed in case of BDR-10 and DBV where the BDR -10 has higher cocoon weight 12.85 and DBV has 12.45 but the shell weight which is equivalent to available silk was found higher in DBV (1.73) instead of BDR-10 (1.71).

At the same time higher shell weight also doesn't guarantee the higher raw silk yield/productivity as it is affected by Filament Length, NBFL, reelability and boil off loss. DBV cocoons have higher shell weight (1.73) than BDR-10 (1.71) but due to comparable low NBFL & reelability, DBV has lower raw silk recovery (62.14) and lower productivity in terms of no. of cocoons required to produce 1 kg raw silk (1111) as compare to BDR-10 which gives 64.84 raw silk recovery and 1049 cocoons required to produce 1 kg raw silk.

Out of the 3 races, BDR-10 has performed better in terms of cocoon weight, productivity, raw silk recovery, NBFL & reelability whereas the DBV

performed better in terms of shell weight, Filament length, Boil off loss and denier, it gives finest filament among all 3 races. DTV showed better Shell ratio but performed weaker in other important parameters which are significant for productivity. BDR-10 cocoons found to be best for productivity whereas DBV was found to be a balanced option for both productivity and quality as it gives finer filament whereas DTV can also be utilized for commercial reeling with more precautions during cooking and reeling.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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