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Evaluation of cocoon characters of outdoor and total indoor reared tasar silkworm *Antheraea mylitta* D (Daba TV ecorace)

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ABSTRACT

Tasar silkworm, *Antheraea mylitta* Drury (Daba TV), a wild tropical sericigenous insect, reared in outdoor conditions is facing pest and predator problems that lead to extremely low cocoon yield. In order to overcome this problem, a novel method of indoor rearing has been conducted. Tasar cocoons are very hard and compact in nature, producing long and lustrous silk. In the present study, the cocoon parameters were studied from the crops raised by seeds obtained from outdoor and total indoor reared moths. A comparative study is made on the cocoon parameters viz., length, width, shell weight, shell thickness, shell ratio, cocoons per kg and Effective Rate of Rearing (ERR). Though there are several ecoraces of tasar silkworm like Daba, Sukinda and Jata, which have certain phenotypic variations and have been semi-domesticated, *i.e.*, upto 3rd instar, in the present study the rearing of tasar ecorace Daba TV has been undertaken in indoor conditions from hatching to spinning stage and has been successful in obtaining three crops per year. The observations on cocoon parameters have shown a considerable improvement in the cocoon length, width, thickness and shell ratio in the crop reared by indoor seed source. However, a slight decrease in ERR was observed which may be due to fluctuations in natural environmental conditions, that contribute to better performance of the cocoons.

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INTRODUCTION

The *Antheraea mylitta* Drury, Daba ecorace, native of Singhbhum of Jharkhand is available in two forms based on voltinism *viz*., Bi and Tri-voltine. According to the latest survey on tasar silkworm done by Srivastava and Suryanarayana [1], the main features of *Antheraea mylitta* Drury, Daba ecorace, are emergence capacity of 91.19%, mating capacity of 76.10%, average fecundity of about 250, cocoon weight of 16.39 gm and shell weight of 2.65 gm. It has reelability, shell ratio, filament length and denier of 16.76%, 69%, 1010 m and 9%, respectively.

The tasar silkworm, Daba TV ecorace has been facing problems during outdoor rearing like heavy mortality of larvae due to predators and parasites [2], irregular hatching of eggs leading to prolonged larval period, climatic hazards [3], indefinite period of diapause leading to erratic moth emergence followed by inadequate seed support and other grainage problems [4]. There is a dearth of appropriate technologies especially in post-cocoon sector and marketing facilities. In the post-cocoon stage this race suffers certain drawbacks like lack of uniformity in cocoon structure, silk deposition and cocoon boiling due to their hardness which accounts for 50% silk loss during spinning.

Rearing being outdoors, there is a certain extent of crop loss due to parasites and vagaries of nature, which affect the yield of cocoons. Further, the low

egg-laying capacity (150-200), prolonged larval duration of the commercial crops and irregular hatching of eggs *etc.*, pose severe constraints. Besides the cocoon uniformity and efficiency, reelability percent and yarn productivity have their own limitations. Seed organization, marketing of tasar cocoons, yarn and fabrics are still unorganized sectors in tasar cocoon production [5].

In the present investigation, an attempt has been made for total indoor rearing of *Antheraea mylitta* Drury, Daba TV in which rearing of silkworm has been undertaken from brushing stage to the cocooning stage in the controlled conditions for the three crops *i.e.*, from June to December, in the rearing set-up designed in the laboratory. Simultaneously, outdoor rearing was also done on *Terminalia arjuna* plantation raised in Sericulture Unit, Kakatiya University. The physical parameters of larvae like length, weight, colour and mortality and larval duration are studied for both indoor and outdoor reared larvae. The cocoon, post-cocoon and peduncle parameters of both outdoor and indoor reared larvae are studied and compared. A comparative analysis of biochemical estimations were also done in the late fourth and fifth instar larvae and presented in the results.

MATERIALS AND METHODS

Studies on cocoon, post-cocoon and peduncle characters

The present study comprises of a comparative evaluation of certain physical and morphological characters of outdoor and indoor reared Tasar silkworm, *Antheraea mylitta* D, Daba TV ecorace, in three crops (June–July, Aug–Sep and Dec–Jan).

Indoor rearing method

Indoor rearing set-up consists of conical flasks or wide mouth bottles, rather, any water containers which can ensure constant water supply to the branches. The mouth of the conical flask or bottle was plugged with cotton to protect larvae from drowning and also to check any increase in humidity due to evaporation of water (Fig. 1). The average number of worms on the twigs inserted in conical flasks for I, II, III, IV and V instars were 100, 75, 50, 25 and 15, respectively. A paraffin paper was used to collect the faecal pellets and to maintain cleanliness and healthy atmosphere in the rearing set-up. This rearing set-up was surrounded by *vetiveria* curtains (water sprinkled vatti vellu mats) to maintain more humidity in the indoor rearing environment [6, 7]. Rearing starts with shifting of newly hatched caterpillars onto the host plant leaves present in the conical flasks. The *Terminalia arjuna* twigs were changed thrice per day till the fifth instar and the process were continued until cocoon formation. For evaluation of cocoon parameters, well-formed cocoons were selected at random, 10 cocoons from each lot of indoor and outdoor rearing set-up.

Reeling of tasar cocoons

The reeling of cocoons means obtaining raw silk from the cocoons. Tasar cocoons are very hard and do not become soft in spite of prolonged boiling in water. This unusual hardness of the cocoons makes them unreelable, causing lower silk yield and inferior quality of silk. An improved technique has been developed by Moon *et al.* [8], according to which cocoons are first boiled for 5-10 min in 1% soda and 1% soap solution and then steamed for one hour at 15 lbs followed by overnight soaking in 0.2 to 0.5% of di ammonium phosphate (D.A.P.) solution, initially at 45-47 °C and then left at room temperature. Akai *et al.* [9] used Bipril-50 for soaking the cocoons, which were then semidried by spreading on ash bed and then the cocoons were used for reeling on dry basin.

Cocoon and post-cocoon parameters

The following cocoon parameters were studied.

The cocoon length and width were measured using Vernier Calipers in cm and the shell thickness was measured using Screw Gauge. The cocoons were cut open carefully and the pupa was separated before calculating the shell weight and cocoon thickness (Fig. 2).

The reeled silk weight was measured in grams with the electronic digital balance of Shimadzu (Model: TX323L).

Reelability = [Weight of the silk reeled/Weight of the cocoon] X 100

Denier = [Weight of the silk reeled/Length of the silk reeled] X 9000

Filament length = 9/8 m X No. of revolutions

Effective Rate of Rearing (ERR):

ERR by Weight = [Weight of total number of cocoons produced/Total number of larvae brushed] X 100

ERR by Number = [Total no. of cocoons produced/ Total no of larvae brushed] X 100

Shell Ratio = [Shell Weight/Cocoon Weight] X 100

Microscopic observation of surface view of cocoon shell and filament

For the microscopical study, 1 mm thick cocoon shell was prepared to be observed under the microscope. First the cocoons were cooked for about 2 hrs with 1% soda solution and soaked in cold water in which hydrogen peroxide was added to strengthen the cocoon filament. Then it was cut with scissors and kept on the slide by stretching and was taped at ends. The slide was observed under the Olympus tri-ocular light microscope (model: CX 21) under a magnification of 10X (Fig. 3).

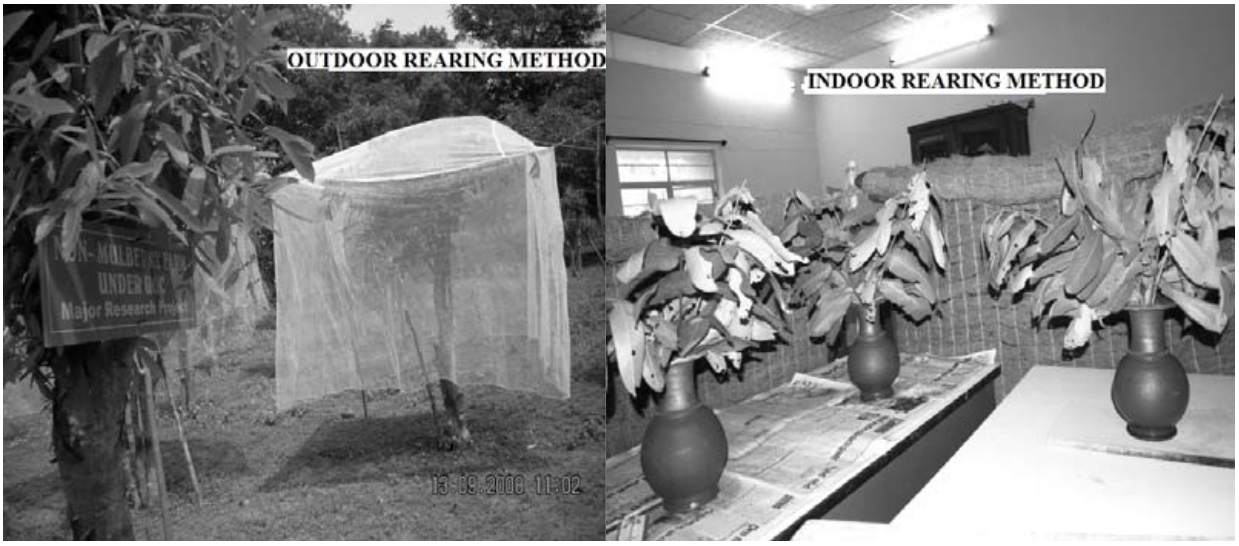

Fig. 1. Rearing of Tasar silkworm *Antheraea mylitta* D, Daba TV.

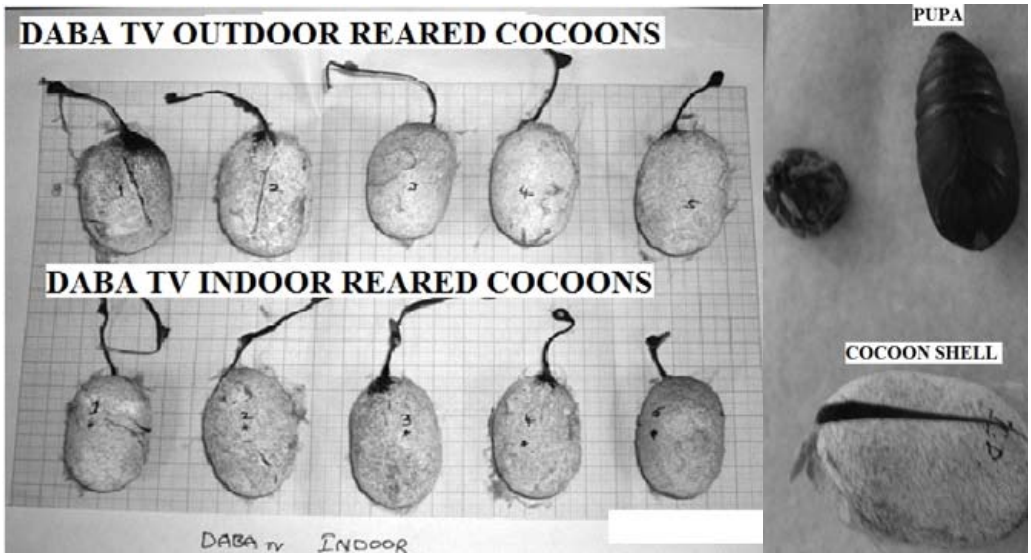

Fig. 2. The Cocoons of Tasar silkworm, Cocoon shell, pupa and exuvia of Tasar silkworm, *Antheraea mylitta* D (Daba TV).

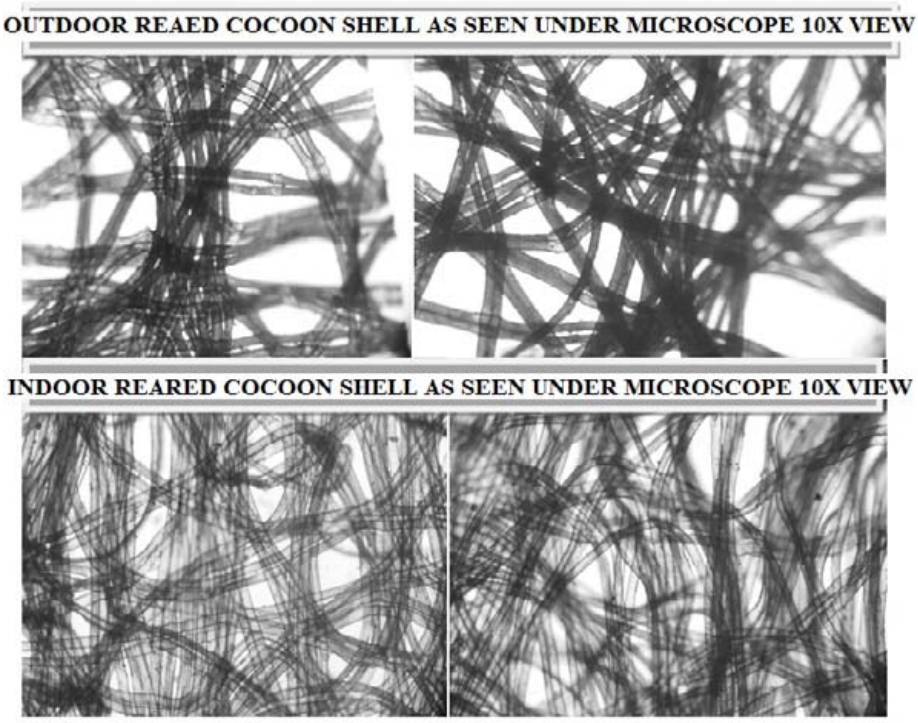

Fig. 3. Cocoon shell of tasar silkworm *Antheraea mylitta* Drury, Daba TV.

RESULTS

The cocoon characters of outdoor and indoor reared tasar silkworm, *Antheraea mylitta* Drury (Daba TV) for the three crops per year are presented in Table 1. The cocoon parameters include cocoon weight (gr), shell weight (gr), pupal weight (gr), length of shell (cm), width of shell (cm), thickness of shell (mm), length of the peduncle (cm), weight of the peduncle (gr) and shell ratio (%).

In the first crop of outdoor rearing the cocoon parameters were 12.76 ± 1.20 (S. D.), 1.65 ± 0.12 (S. D.), 10.21 ± 0.15 (S. D.), 5.872 ± 0.12 (S. D.), 2.87 ± 0.04 (S. D.), 0.81 ± 0.12 (S. D.), 2.67 ± 0.03 (S. D.), 5.32 ± 0.02 (S. D.), 0.03 ± 0.03 (S. D.) and 12.93%, respectively while that of indoor rearing were 11.73 ± 1.43 (S. D.), 1.32 ± 1.44 (S. D.), 9.61 ± 0.21 (S. D.), 5.232 ± 0.31 (S. D.), 1.98 ± 0.26 (S. D.), 0.74 ± 0.23 (S. D.), 2.99 ± 0.07 (S. D.), 5.33 ± 0.06 (S. D.), 0.04 ± 0.02 (S. D.) and 11.25%, respectively.

In the second crop of outdoor rearing the cocoon parameters were: 11.56 ± 1.21 (S. D.), 1.49 ± 0.82 (S. D.), 8.92 ± 0.32 (S. D.), 5.676 ± 0.42 (S. D.), 2.64 ± 0.65 (S. D.), 0.83 ± 0.06 (S. D.), 2.65 ± 0.04 (S. D.), 5.63 ± 0.07 (S. D.), 0.02 ± 0.01 (S. D.) and 12.88%, respectively while those of indoor rearing method were 10.58 ± 2.16 (S. D.), 1.08 ± 1.65 (S. D.), 8.7 ± 0.54 (S. D.), 5.23 ± 0.23 (S. D.), 1.89 ± 0.31 (S. D.), 0.71 ± 0.12 (S. D.), 2.44 ± 0.03 (S. D.), 5.31 ± 0.07 (S. D.), 0.06 ± 0.03 (S. D.) and 10.20%, respectively.

In the third crop of outdoor rearing the cocoon parameters were 12.11 ± 2.45 (S. D.), 1.65 ± 1.45 (S. D.), 9.56 ± 1.54 (S. D.), 5.723 ± 0.54 (S. D.), 2.098 ± 0.42 (S. D.), 0.82 ± 0.01 (S. D.), 2.23 ± 0.05 (S. D.), 5.76 ± 0.01 (S. D.), 0.09 ± 0.04 (S. D.) and 13.62% while that of indoor rearing were 10.17 ± 1.27 (S. D.), 1.43 ± 0.32 (S. D.), 7.94 ± 1.42 (S. D.), 5.243 ± 0.74 (S. D.), 2.43 ± 0.21 (S. D.), 0.80 ± 0.02 (S. D.), 2.15 ± 0.08 (S. D.), 5.22 ± 0.06 (S. D.), 0.08 ± 0.03 (S. D.) and 14.0%, respectively.

The post-cocoon characters like weight of reeled silk (gr), length of the filament (m), reelability (%), denier (%), effective rate of rearing (ERR) by weight and ERR by number in outdoor and indoor reared tasar silkworm, *Antheraea mylitta* Drury (Daba TV) for three crops were calculated and are presented in Table 2.

Table 1. Cocoon characters of outdoor and indoor reared tasar silkworm *Antheraea mylitta* Drury (Daba TV) during three crops of 2008-2010.

Year	Crop	Rearing	Cocoon Wt	Shell Weight	Pupal Weight	Length of shell	Width of shell	Shell thickness	Peduncle thickness	Peduncle length	Weight of the peduncle	Shell ratio (in %)
III (2010)	I (Jun-Jul)	Outdoor	12.76 ± 1.20	1.65 ± 1.22	10.21 ± 0.15	5.872 ± 0.12	2.87 ± 0.04	0.81 ± 0.15	2.67 ± 0.03	5.23 ± 0.41	0.03 ± 0.03	12.93
		Indoor	11.73 ± 1.43	1.32 ± 1.44	9.61 ± 0.21	5.232 ± 0.31	1.98 ± 0.26	0.74 ± 0.23	2.99 ± 0.07	5.33 ± 0.06	0.04 ± 0.02	11.25
	II (Aug-Sep)	Outdoor	11.56 ± 1.21	1.49 ± 0.82	8.92 ± 0.32	5.676 ± 0.42	2.64 ± 0.65	0.83 ± 0.06	2.65 ± 0.04	5.63 ± 0.07	0.02 ± 0.01	12.88
		Indoor	10.58 ± 2.16	1.08 ± 1.65	8.7 ± 0.54	5.23 ± 0.23	1.89 ± 0.31	0.71 ± 0.12	2.44 ± 0.03	5.31 ± 0.07	0.06 ± 0.03	10.20
	III (Dec-Jan)	Outdoor	12.11 ± 2.45	1. 65 ± 1.45	9.56 ± 1.54	5.723 ± 0.54	2.098 ± 0.42	0.82 ± 0.01	2.23 ± 0.05	5.76 ± 0.01	0.09 ± 0.04	13.62
		Indoor	10.17 ± 1.27	1. 43 ± 0.32	7.94 ± 1.42	5.243 ± 0.74	2.43 ± 0.21	0.80 ± 0.02	2.15 ± 0.08	5.22 ± 0.06	0.08 ± 0.03	14.0

Table 2. Post-cocoon characters of outdoor and indoor reared tasar silkworm *Antheraea mylitta* Drury (DabaTV) 2008-2010.

Year	Crop	Rearing type	Reeled silk wt (grms)	Filament length (m)	Reelability (%)	Denier	Effective rate of rearing by weight	Effective rate of rearing by number
I	I (June-July)	Outdoor	0.478	778	3.74	6.44	93.8	57.5
		Indoor	0.464	627	3.95	6.22	94.1*	70.5*
	II (Aug-Sep)	Outdoor	0.491	645	3.98	6.91	76.4	64.8
		Indoor	0.401	531	4.40	6.79	76.4	70.7*
	III (Dec-Jan)	Outdoor	0.459	542	3.79	7.62	65.7	64.8
		Indoor	0.450	562	4.42	7.20	81.5*	75.5*

*Significant values of indoor rearing compared to that of outdoor rearing method in tasar silkworm, *Antheraea mylitta*, Daba TV.

In first crop of outdoor rearing, the post-cocoon parameters were 0.478, 778, 3.74, 6.44, 93.8 and 57.5, respectively, while in indoor rearing they were 0.464, 927, 3.95, 6.22, 94.1 and 70.5, respectively.

In the second crop of outdoor rearing the post-cocoon characters were 0.491, 645, 3.98, 6.91, 76.4 and 70.8, respectively, while those of indoor rearing were 0.401, 531, 4.40, 6.79, 76.4 and 70.7, respectively.

In the third crop of outdoor rearing the post-cocoon characters were 0.459, 542, 3.79, 7.62, 65.7 and 64.8 while in indoor rearing they were 0.450, 562, 4.42, 7.20, 81.5 and 75.5, respectively.

From the microscopic studies, it was observed that in the indoor reared cocoons, there were lesser gaps between the silk filaments and the thickness of the fibre was also found to be less; on the other hand, wider gaps with thick filaments were observed in the outdoor reared cocoons.

DISCUSSION

The cocoon characters of first, second and third crops of indoor rearing were compared with those of outdoor reared samples. Most of the characteristics such as cocoon weight, shell weight, length of the shell, shell thickness, peduncle thickness, peduncle length & weight, denier and shell ratio have shown clear distinction and superiority in the outdoor reared cocoons. The reeled silk weight for indoor reared cocoons was at par with those of outdoor reared ones. However, the reelability and ERR (by weight) were significantly higher in indoor reared cocoons than those of outdoor reared ones. The ERR (by number) has shown occasional increase in some of the crops in the three years of indoor rearing.

Though earlier reports [10] have concluded that short time rearing of tender worms under indoor conditions resulted in lessening of mortality rate and betterment of cocoon, most of the studies have confirmed that indoor rearing up to third instar is feasible for commercial purposes, but some studies have shown that cocoon characters can be improved in the presence of phago-stimulants, sucrose and glucon–C [11, 12]. Srivastava *et al.*, [13], have reported that the cocoons of Daba ecorace produced under identical conditions in different seasons are not uniform in their qualitative and quantitative characters. In the present study, differences in cocoon characters are observed in the same season, but under different environmental conditions.

The quality of the cocoons is assessed by its commercial characters like thickness of shell, hardness, shell ratio, filament length, reelability and low denier. These characters are found to be superior in Indian tropical tasar *A. mylitta* cocoons among all the other known non-mulberry silk producing insects [11, 14]. The silk protein fibroin is fibrous in nature, forming the main silk filament content, while sericin is a sticky coating substance between the layers of fibroin. Thus, the quality of cocoons depends both on sericin and fibroin which are controlled by atmospheric conditions. The presence of more cementing substance (sericin) and less filament (fibroin) in the indoor cocoons suggests the role of environmental factors on the synthesis of these two proteins by the silk gland [15]. Some studies have reported [16] that sericin content is the deciding factor in assessing the quality of the cocoon and raw silk reeled.

A recent work on total indoor rearing of tasar silkworm *Antheraea mylitta* D, Andhra local ecorace, done by using selected leaves and optimum conditions of temperature and relative humidity, revealed that substrates like trehalose, glucose, protein, amino acid and uric acid contents in the haemolymph and fat body were found to be higher in tasar silkworms reared in indoor conditions, than those of outdoor reared ones, which face fluctuating environmental conditions, quality changes in the leaf and photoperiodism. The increased amino acid content of the haemolymph in the indoor worms might be due to high proteolytic activity or reduced breakdown of amino acids due to slow and restricted movements of the worm, leading to less activity and lesser consumption of leaf, resulting in poor quality of the cocoons [17].

The indoor cocoons were found to be delicate when compared to relatively harder cocoons of outdoor reared ones. In the indoor rearing method, some cocoons were spun with double peduncles. This might be due to lack of suitable place for spinning in indoor rearing method. The lesser cocoon weight and silk filament weight in indoor reared cocoons suggest that though they were smaller in size, their compactness and higher reelability might play an important positive role in assessing seed cocoon quality by the breeders in cocoon price fixing in seed cocoon markets [18].

According to recent studies, the role of parental selection and combination in successive rearing seasons can be utilized to improve commercial traits of Daba ecorace to evolve commercial silkworm breeds with higher fecundity and shell weight [19]. It can be concluded that indoor rearing can be improved further by selecting high yielding varieties to supplement the commercial silk yield. It is also established that the knowledge of cocoon characters in varied seasons and ecopockets is an important tool in breeding work [20].

In view of the frequent crop losses in tropical areas due to aggravated silkworm diseases coupled with unfavourable weather conditions despite the disinfection measures adopted, the present study gives a promising future for indoor rearing of the wild silkworm which is now being semi-domesticated. It may lead to the fulfillment of the endeavors of many sericologists, who are still making concerted efforts towards complete domestication of this wild silkworm. An important observation from this study is that there was no loss of worms due to rainfall and pests in indoor rearing method and also a decreased occurrence of bacterial and viral diseases was found in this novel rearing method. It is also corroborated by the view that a genotype with disease resistance always has much more chance to survive [21].

The study infers that indoor rearing can be sustainable from a commercial point of view under the following conditions:

i. The methodology needs to be applied on a large scale to reach the farmer.
ii. The indoor reared cocoons should be utilized as seed crop for the successive years.
iii. The cocoon parameters need a significant improvement in the indoor rearing conditions.
iv. The silk yield should increase.

The cocoon characters of first, second and third crops belonging to indoor rearing were compared with outdoor reared samples. Most of the characteristics such as cocoon weight, shell weight, length of the shell, shell thickness, denier and shell ratio have shown clear distinction and superiority in the outdoor reared cocoons. The reelability and ERR (by number) were significantly higher in indoor reared cocoons than those of outdoor reared ones. The ERR (by weight) has shown occasional increase in some of the crops in the three years of indoor rearing. Moreover, the cocoon yield in the indoor rearing is higher than that of outdoor rearing, while loss of cocoons is higher in outdoor rearing, which is a significant and commercially important observation.

CONCLUSION

It can be concluded that the present work, which is directed towards the improvement of total indoor rearing practices of the tasar silkworm *Antheraea mylitta* Drury (Daba TV) reveals a considerable improvement in the commercial aspects of indoor rearing. In the present investigation, though the silk yield has improved significantly, most of the cocoon parameters need to be improved further so as to enable commercial viability of indoor rearing. The present study based on quantitative traits needs analysis to understand the genetic basis of the phenotype. The study needs to go further to develop more appropriate strategy for the conservation of the Tasar silkworm, *A. mylitta*, by improvising the present indoor rearing technology.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

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