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Rearing performance of tropical Tasar silkworm (*Antheraea mylitta* Drury) on Cashew (*Anacardium occidentale* L.) and its commercial silk properties

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Abstract: Tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) is one of the commercially exploited non-mulberry silkworms mainly reared outdoor on many wild plants. The ecorace of tasar silkworm occurring in cashew (*Anacardium occidentale* L.) plantations of Puttur was identified as *A. mylitta* KE-02. Pooled egg, larval and pupal period of tasar silkworm upon indoor rearing on cashew recorded were 6.43, 28.69 and 25.36 days, respectively, with the effective rate of rearing of 40 %. The average cocoon weight, pupal weight and shell weight recorded were 6.24 g, 5.30 and 1.18 g, respectively. The high shell ratio of 22.26 %, shows a healthy trend for high yielding tasar rearing on cashew. The commercial silk properties of cashew reared cocoons were assessed in comparison to silk properties of cocoons reared on *Terminalia paniculata*. Average filament length, average non-breakable filament length, denier, strength and elongation were found 547.2 m, 1231.6 m, 8.92 D, 1.57 gpd and 16.9 %, respectively on cashew and 518.2 m, 161.94 m, 9.13 D, 1.73 gpd and 18.7 % , respectively on *T. paniculata*. The present study has documented the biology of tasar silk worm on cashew and also the commercial silk properties of cocoon reared on cashew at preliminary level.

Keywords: *Antheraea mylitta*, Cashew, Cocoon, Eggs, Larvae, Spinning, *Terminalia* spp.

INTRODUCTION

Cashew (*Anacardium occidentale* L.), is an important cash crop, grown in Asian countries, East African countries, Brazil and in some packets of Sri Lanka, Australia, etc. In India, it is mostly grown in degraded marginal lands in around 9.82 lakh ha (CN, 2013). Since cashew is mostly grown by poor farmers, it is being called as 'poor man's crop, but rich man's food' (Nair, 2010). Hence, any entrepreneurial activity that help in better livelihood of cashew farmers will improve their economic status, and sericulture can be one such activity. Incidence of tasar silkworm on cashew in the study area and the lack of information on its rearing performance prompted to take up this work. Tasar cocoons are the largest among all the silk-producing insects in the world (Akai, 2000) and its silk fibre has its own distinctive colour, higher tensile strength, elongation and stress-relaxation values than the mulberry silk fibre (Iizuka, 2000).

Primary host plants of tasar silkworm include *Terminalia arjuna*, *T. tomentosa* and *Shorea robusta* while, more than 15 plants were reported as secondary hosts (Agarwal, 1999, Jolly *et al.,* 1968, Suryanarayana and Srivastava, 2005). Traditional rearing of tasar silkworm on forest grown trees resulted in 80-90% crop loss due to pests, predators, natural calamities and diseases (Mathur and Shkla, 1998). Thus indoor rearing looks rational to make tasar culture more economical. Polyphagy as well as wide distribution had resulted in extensive variation in *A. mylitta* population and in 16 states of India, as high as forty four ecoraces have been reported so far (Srivastava and Sinha, 2015). The variation in the qualitative and quantitative characters in relation to host plants among a few tasar producing insects have been investigated earlier by Sharma *et al.* (1998). But, identification and exploitation of many of the ecoraces of tasar silkworms are to be taken care for economic production of sericulture farmers of a particular locality. Rearing studies of *A. mylitta* on cashew (Singh *et al*., 2009), *Lagerstroemia* sp. (Reddy *et al.,* 2010 a,b), *Terminalia* spp., *S. robusta, Zizypus jujuba* (Jadhav, 2014) and *Syzygium cumini* (Kavane, 2014) showed that tasar is no averse to indoor rearing. The present study location also has several host plants like *Terminalia arjuna*, *T. tomentosa*, *T. catapa* and *T. paniculata* Roth. (Combretaceae) (Jolly *et al.,* 1968), among which *T. paniculata* is common. Present investigation attempted to identify the ecorace of the tasar silkworm occurring in the study region and to assess its indoor rearing feasibility on cashew, besides its commercial

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silk properties. Besides, the study was also aimed to record the commercial silk properties of this tasar silkworm ecorace reared on *T. paniculata*.

MATERIALS AND METHODS

Larvae of *A. mylitta* were collected from cashew plantations of Directorate of Cashew Research, Puttur during June, 2014 and kept under laboratory conditions at 28 ± 2°C temperature, 90 ± 5% RH. Larvae were fed with field collected fresh cashew shoots having 5-7 leaves kept in water filled vials fixed on a rack. The mouth of the vials was plugged with cotton to protect larvae from drowning and also to check any increase in humidity due to evaporation of water. The whole set was kept inside cylindrical transparent plastic boxes of 6.5 L capacity and covered with wet muslin cloth. Tissue papers were kept at the bottom of the boxes to gather faecal pellets and to maintain cleanliness and healthy environment in the rearing set following Tembhare and Barsagade (2003). Larvae were transferred regularly in to the fresh shoots as and when required, and the moulting or ready to moult larvae were transferred along with their support leaves. The grown up larvae were allowed for cocoon formation in the shoot itself. Cocoon harvesting was done after the seventh day of spinning and were kept inside the polystyrene boxes of 40 cm^3 having many tiny holes for aeration. Dried cashew sticks were provided as support for emerging adults. Emerged adults were allowed for pairing and egg laying in the boxes.

Incubation period was recorded and the hatched larvae were reared further to record the biology. First instar larvae were carefully transferred using a camel hair brush to the tender cashew shoots @ 20/ shoot kept inside plastic boxes in vials containing water. Every day, fresh shoots were provided and the boxes were changed once in three days to maintain cleanliness. Care was taken to provide fresh shoots as and when required. Larvae were kept @ 10/ shoot, 6/ shoot, 3/ shoot and 1/shoot during 2^{nd}, 3^{rd}, 4^{th} and 5^{th} instar stages, respectively. The final instar larvae were allowed for spinning in the cashew shoot itself and the cocoons were transferred to the polystyrene boxes as previously mentioned for adult emergence and subsequent egg laying. Rearing studies were conducted using 120 larvae during Jul - Aug 2014 and 100 larvae during Sep - Nov 2014 to record duration of larval instars, pupa, adult, oviposition, post oviposition, as well as final instar larval weight, cocoon weight, pupal weight, shell weight and shell ratio.

Shell ratio (%) was obtained using the formula:

Shell ratio (%) = [weight of cocoon shell (g) / weight of whole cocoon (g)] x 100

Besides, fecundity of female moths, and hatchability of eggs were also recorded. Similarly, a set 50 just hatched larvae of *A. mylitta* was maintained on shoots of *T. paniculata* to obtain cocoons for assessing comparable silk properties. The effective rate of rearing (ERR) was calculated as follows:

$$\text{ERR (\%)} = \frac{\text{Total number of cocoons harvested}}{\text{Initial number of larvae reared}} \text{x100}$$

A set of cocoons were submitted at Central tasar research and Training Institute (CTRTI), Ranchi, India for authentication of its ecorace. The silk parameters of *A. mylitta* cocoons reared on cashew as well as on *T. paniculata* were assessed at Central Silk Technological Research Institute (CSTRI), Bengaluru, India. Sorting of cocoons, stifling, cooking and reeling were

Table 1. Developmental duration and mortality of *A. mylitta* at different stages on cashew.

Developmental stage	Duration (days) Mean ± SEM			Mortality (%) at particular stage (Sep-Nov)	Cumulative mortality (%)
	Jul- Aug (x=120)	Sep-Nov (x=100)	Pooled		
Egg	6.12±0.11	6.51±0.21	6.43 ±0.17	3.23	3.23
1^{st} instar	4.42±0.15	5.33±0.14	4.71±0.19	3.33	6.67
2^{nd} instar	3.33±0.14	4.58±0.15	3.50±0.17	9.20	15.56
3^{rd} instar	5.00±0.21	5.28±0.15	5.14±0.21	10.13	24.44
4^{th} instar	5.92±0.23	6.17±0.24	6.07±0.20	29.58	47.78
5^{th} instar	10.42±0.15	10.58±0.19	10.43±0.18	28.00	60.00
Pupa	21.08±0.23	29.08±0.23	25.36±0.68	0.00	60.00

(x= initial population)

Table. 2. Larval weight, cocoon characteristics, adult longevity and grainage parameters of *A. mylitta* on cashew (x=100).

S. N.	Parameters	Mean±SEM	S. N.	Parameters	Mean±SEM
1	Matured fifth instar larval weight (g)	17.1±0.21	8	Male longevity (d)	3.21±0.11
2	Cocoon weight (g)	6.24±0.39	9	Male wing span (cm)	12.7±0.05
3	Pupal weight (g)	5.30±0.22	10	Preoviposition period (d)	1.06±0.07
4	Shell weight (g)	1.18±0.18	11	Oviposition period (d)	3.68±0.13
5	Shell ratio (%)	22.26	12	Post oviposition period (d)	2.75±0.12
6	Female longevity (d)	7.79±0.19	13	Fecundity (Nos)	182.8±6.19
7	Female wing span (cm)	14.1±0.02	14	Hatchability (%)	96.78

(x= initial population)

Table 3. Comparative rearing and reeling parameters of *A. mylitta* on cashew and *T. paniculata* (x=100, 50 respectively).

S. N.	Parameters	On Cashew Mean±SEM	On *T. paniculata* Mean±SEM	t test
Developmental parameters				
1.	Total larval developmental period (d) (including the durations of moulting)	28.69±0.60	27.46±0.39	NS
2.	Final instar larval weight (g)	16.83±0.16	17.15±0.17	NS
Cocoon parameters				
3.	Cocoon weight (g)	6.24±0.39	6.37±0.41	NS
4.	Cocoon length (cm)	3.58±0.06	3.54±0.09	NS
5.	Cocoon breadth (cm)	2.05±0.04	1.94±0.05	NS
6.	Peduncle length (cm)	2.88±0.40	1.09±0.16	2.88
7.	Peduncle width (cm)	1.97±0.13	1.82±0.16	NS
Silk parameters				
8.	Average filament length (m)	547.2±10.40	518.2 ±14.88	2.38
9.	Average NBFL (m)	121.6	161.94	2.67
10.	Average Denier (D)	8.92±0.09	9.13±0.16	NS
11.	Strength (gpd)	1.57±0.03	1.73±0.02	3.93
12.	Elongation (%)	16.9±0.17	18.70±0.18	8.29

NS (non- significant) at 0.05 % level, (x= initial population)

carried out by adopting standard techniques. Standard equipments developed at CSTRI, Bengaluru were used to study the average filament length, average non-broken filament length NBFL (m), average denier (D), strength (gpd) and elongation (%).

RESULTS

Under field observation between 2012 and 2014, incidence of tasar silkworm, *A. mylitta* was recorded initially on young cashew plants from June onwards, more during July-September but noticed up to February on old trees as well. Singly (rarely two) laid creamy flat-ellipsoidal eggs were seen on either upper or lower side of semi mature cashew leaves and a part of chorion was invariably eaten away by larvae upon hatching (Fig. 1a and b). Later, the larvae moved on to

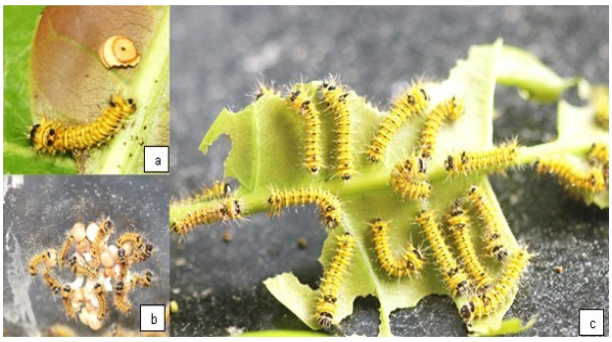

Fig. 1. *(a) hatched larva of A. mylitta and the fed chorion (b) a batch of hatched larvae in lab (c) 1st instar A. mylitta larvae feeding on a cashew leaf.*

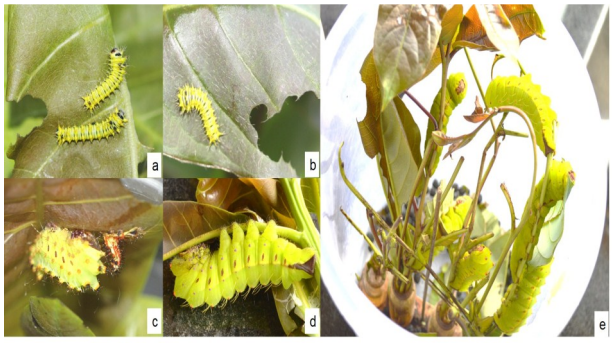

Fig. 3. *Rearing of A. mylitta : a. 2nd instar larvae on cashew b. 2nd instar larvae on T. paniculata c. 4th instar larva just moulted, d. 5th instar larva on cashew e. 5th instar larvae on T. paniculata under rearing set up.*

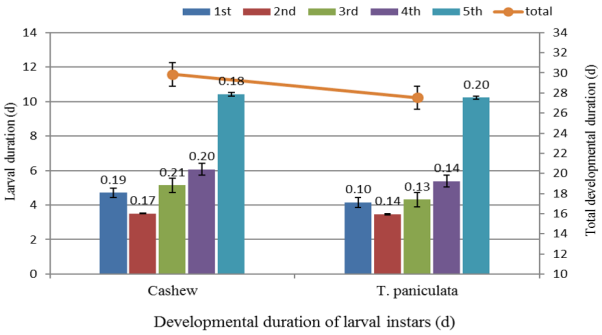

Fig. 2. *Comparative larval span of A. mylitta on cashew and T. paniculata.*
(Values above error bars of each column represent standard error mean)

Fig. 4. *(a) Cocoon spun on cashew (b) NPV infested 5th instar larva (c) silkmoths –male (top) and female (bottom).*

tender leaves on the shoots for feeding (Fig 1c). In the infested trees, tender as well as matured cashew leaves including midribs were eaten away by silkworms and a lot of faecal pellets were seen on the ground. Under field conditions, incidence was noticed in ~ 1-2 % of cashew trees with very less population (2-3 larvae/ tree), and the infested trees yielded normally subsequently.

The ecorace of tasar silkworm occurred on cashew in the study region has been identified as *A. mylitta* KE-02 and this ecorace is reported for the first time from Karnataka. Under lab conditions, egg incubation period observed was 6.43 days. Egg mortality was observed at 3.22 % due to dryness and unknown reason. Mortality of 1st instar *A. mylitta* was very less (3.33 %) and the larvae turned in to second instar in 4.71 days (Table 1). The larvae could complete all five instars successfully in 26-31 days on cashew and 25-29 days on *T. paniculata* (Fig. 2). Larval instars and rearing set up is shown in Fig 3a-3e. During pre-moulting and moulting, larvae remained without feeding for nearly 26 hours. Each larva fed 35-41 cashew leaves of varying sizes before spinning, and feeding was voracious during fifth instar (24-29 leaves). As compared to all other instars, duration of fifth instar was longer (10.43 days). Cumulative mortality was very less during Jul – Aug (25 %), while, in Sep- Nov, mortality of larvae recorded were 9.20, 10.13, 29.58 and 28 % during 2nd, 3rd, 4th and 5th instars, respectively and the total cumulative larval mortality recorded was 60 % (Table 1). Matured silkworms spun cocoons by joining adjacent leaves and the creamy yellow oval cocoons with peduncles were seen on the cashew shoots (Fig. 4a). The mortality of larvae during late instars was primarily because of nucleo polyhedrosis virus (NPV) infection that occurred accidently and also by the warmer temperature prevailed during October. NPV infected larvae were sluggish, pale and hanged its head downwards after death. There was complete disintegration of tissues and degenerated tissues oozed out from its mouth as dark brownish fluid (Fig. 4b).

The cocoons were single-shelled, pendent and oval. At the anterior end of cocoons, peduncle was formed in 79.6 % of cocoons, while 20.4 % cocoons were without peduncle. If present, the peduncle was dark brown having a ring at the distal end. On cashew, the commercially important cocoon traits such as average cocoon weight, pupal weight and shell weight recorded were 6.24 g, 5.30 and 1.18 g, respectively. Interestingly, though cocoon weight was less, shell weight was more, hence the shell ratio obtained was very high (22.26 %) (Table 2). After a week of spinning, average length and breadth of cocoons were 3.58 cm and 2.05 cm on cashew, and 3.54 cm and 1.94 cm on *T. paniculata,* respectively (Table 3).

The moths exhibited distinct sexual dimorphism. The females were yellowish, bigger than males (Fig. 4c), with distended abdomen and narrow bipectinate antennae, whereas, the males were yellowish brown and smaller (Fig. 4c). Longevity of females was more (7.79 days) compared to males (3.21 days). Female moths mated on the day of emergence and laid fertilized eggs next day onwards in the floor and sides of the boxes. Maximum number of eggs was laid on 1st day of oviposition (80.33 %) and egg laying lasted for the next three to four days. Fecundity was 165 to 193 eggs/ female (mean=182.8±6.19), and egg hatchability was 96.78 per cent which was maximum on the first day. Upon reeling, the quality of commercial silk was also found superior bestowed with comparable properties. Average filament length of silk was more on cashew (547.2 m) than on *T. paniculata* (518.2 m). Average NBFL and Denier were 121.6 m and 8.92 on cashew while, they were 161.94 m and 9.13 on *T. paniculata*. Elongation percentage was 16.9 % for cashew and 18.7 % for *T. paniculata*. Statistically reliable differences of average filament length, average NBFL, strength and elongation of silk between cocoons reared on cashew and *T. paniculata* were revealed by‘t’ test (Table 3).

DISCUSSION

Under field conditions, eggs of tasar silkworm were seen on either upper or lower side of semi mature cashew leaves followed by tender leaves. According to Shruti *et al.* (2006), early instars of *A. mylitta* preferred semi mature leaves of *T. arjuna* for feeding due to their less protease inhibitor activity compared to young leaves. This *A. mylitta* KE-02 ecorace is reported for the first time from Karnataka. The same ecorace has been previously reported on cashew from Kerala (Srivastava and Sinha, 2015), a neighbouring state of the study region. While, a different ecorace, ‘Belgaum’ has been recorded earlier from Karnataka (Srivastava and Sinha, 2015). According to Renuka and Shamitha (2013), diverse geographic and climatic variations of the distinct areas, leading to existence of different ecoraces and marked differences in not only phenotypical and physiological traits of tasar ecoraces but also in the commercial and technological aspects. Under lab conditions, egg incubation period of tasar silkworm observed was 6.43 days. Each larva fed 35-41 tender cashew leaves of varying sizes before spinning, and feeding was voracious during fifth instar. Hence for a productive tasar culture, cashew growers can employ standard pruning techniques on selected cashew trees in a small area so as to obtain enough shoots during tasar rearing period.

The mortality of larvae during late instars was primarily because of nucleo polyhedrosis virus (NPV). The infected larvae were sluggish, pale and there was complete disintegration of tissues, and degenerated tissues oozed out from its mouth. Similar symptoms

were recorded on NPV infected tasar worms by Shiva Kumar and Shamitha (Shivakumar and Shamitha, 2013). Hence, it is important to curb the viral diseases especially NPV and also to standardize the tasar rearing procedure on cashew in order to realize the full rearing potential of this ecorace. The larvae could complete all five instars successfully in 26-31 days on cashew and 25-29 days on *T. paniculata*. But in Kerala, total larval duration of 35-60 days has been recorded for the same KE-02 ecorace (Srivastava and Sinha, 2015). Short larval span in the present study region is boon to rearers in maintenance point of view involving less labour. Variation in larval span of ecoraces was reported by several workers. Average larval span of Daba ecorace was 31 days, while it was 42 days for Andhra local ecorace when reared on *T. tomentosa* (Renuka and Shamitha, 2013).

At the anterior end of cocoons, peduncle was formed in 79.6 % of cocoons, while 20.4 % cocoons were without peduncle. According to Kavane and Sathe (2007), spinning cocoons without peduncle is an outstanding feature of the success of indoor rearing technique. The cocoons were generally light creamy yellow or whitish grey. According to Suryanarayana and Srivastava (2005), whitish grey is considered as predominant cocoon colour spun by many ecoraces of the tasar silkworm and has commercially good cocoon qualities compared to other types of cocoon. After a week of spinning, average length and breadth of cocoons were 3.58 cm and 2.05 cm on cashew, and 3.54 cm and 1.94 cm on *T. paniculata,* respectively. In Kerala, the KE-02 ecorace had a cocoon weight between 5.77 and 8.26 g (Srivastava and Sinha, 2015). Earlier, the six different ecoraces of *A. mylitta* showed variation in cocoon weight between 4.6 to 17.5 g (Renuka and Shamitha, 2013). Hence it is evident that variation in different traits exists among ecoraces. Though, cocoon weight of cashew reared larvae was less, its shell weight was more resulting in high shell ratio (22.26 %). *A. mylitta* ecoraces reared on *T. arjuna* had shell ratio between 10.09 to 30.36 % in different tasar regions of India (Sharma and Praveen Kumar, 1998, Renuka and Shamitha, 2013). Variation in cocoon characteristics between ecoraces has been ascertained earlier by several workers. According to Srivastava *et al.* (2012) Shorea based ecoraces had higher shell weight and compactness compared to Terminalia based populations. Thus, the high shell ratio obtained in the present study indicates a healthy trend for high yielding tasar rearing especially KE-02 ecorace on cashew.

The female moths of *A. mylitta* reared on cashew were yellowish and bigger than males. Findings of Srivastava *et al*. (2010) indicated that tasar moths of yellow colour can enhance grainage efficiency in terms of fecundity and hatching. Hence, this ecorace may be selected for further seed and breeding programme. Fecundity was 165 to 193 eggs/female, and egg hatchability was 96.78 per cent which was maximum on the first day. Ranjan *et al*. (2012) recorded fecundity of 285 eggs upon indoor rearing of *A. mylitta* on *T. arjuna*. This KE-02 ecorace has been found as trivoltine in Kerala (Srivastava and Sinha, 2015) which is advantageous in commercial rearing to get cocoons continuously. Hence for more economic culture, first generation of this ecorace can be raised as seed crop during July - August, and the commercial crops subsequently during September-December. Upon reeling, the quality of commercial silk was also found superior bestowed with comparable properties. During this investigation, average filament length of silk was more on cashew (547.2 m) than on *T. paniculata* (518.2 m). Previously, silk filament length (m) of Daba, Jata and Raily ecorace were being reported as 475-1240, 840-1550 and 570-1750, respectively on *T. tomentosa*, which is a primary host plant (Reddy *et al.,* 2012). Hence it is understood that silk parameters vary with ecorace as well as host plant. The present study reveals that the tasar silk quality is superior when reared on cashew shoots and has got good commercial values. This is in support of Gavas *et al.* (2013) who reported high quality silk of a wild silk moth, *Cricula trifenestrata* Helfer obtained upon rearing on cashew in Kerala, India.

Conclusion

The present findings at preliminary level indicate that cashew is economic and viable for tropical tasar culture. Obstacles in traditional outdoor rearing of tasar on naturally grown forest trees can be overcome if indoor rearing is implemented, and the KE-02 ecorace shows wide adaptability for indoor rearing. If planned pruning techniques are adopted in cashew, occurrence of silkworm during rainy days, old leaves during non fruiting period and leaves of early flushing stage of cashew can be profitably utilized for tasar culture without reduction in yield of cashew. The present findings established successful indoor rearing of *A. mylitta* on cashew shoots to obtain superior quality cocoons with high shell ratio (22.26 %). It is important to conserve the uniqueness of this ecorace by evolving a systematic breeding programme. But, studies need to be intensified to identify more economic ecorace to understand its full potential. Occurrence of wild silkworm in other cashew growing regions of world needs to be documented as well.

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