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PHENOTYPIC AND BEHAVIOURAL TRAITS OF SOME ECO-RACES OF TASAR SILKWORMS UNDER THE EFFECTS OF DIFFERENT ENVIRONMENTAL CONDITIONS

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ABSTRACT

The paper records information on phenotypic and behavioural traits of eco-races of tasar silkworms. There are 44 eco-races of tropical tasar silk reported from 17 states of India. But 6 eco-races of tasar silkworms are most commonly found. These races are Sarihan, Daba, Jata–Daba, Sukinda and Modal respectively. The differentiation of these races depends upon the environmental factors such as temperature, humidity, rainfall, altitude, photoperiod which have great impact on the biology and voltinism of silkworms. The ambient environmental conditions are such physical factors as temperature, humidity, photoperiod and rainfall. The temperature (24±2 to 28±2°C), relative humidity (74±2 to 88±2%), photoperiod (100–242 hr per month) with (11-12.50 hours), day length, rainfall (230±1 to 260±1 mm) was found successful for developing better yield of life cycle, fecundity, cocoon and absolute silk filament length of tasar silkworms. The eco-races of Sarihan (25°C), Daba (29°C), Jata Daba (30°C) were reared on normal temperature but Sukinda (25°C) and Modal (32°C) in lowest and highest temperature respectively. The relative humidity for the success of the eco-races of Sarihan, Daba, Jata–Daba, Sukinda and Modal were recorded as 80, 82, 85, 75 and 90% respectively. Daba race has maximum reliability among all the eco-races. The eco-races Sarihan and Daba are more productive under present environmental conditions and on the view of reelability more beneficial under large scale exploitation for their commercialization as a cottage industry for its sustainable development.

INTRODUCTION

Tasar silk is produced from the tasar silkworms (Insecta: Lepidoptera: Saturniidae) which has many eco–races principally controlled by prevailing environmental conditions. The tasar silkworm has two varieties viz. tropical and temperate. The species exploited for the culture of tasar silk is the wild variety of *Antherea mylita* Drury which feeds on *Terminalia arjuna*, *Terminalia tomentosa* and *Shorea robusta*. There are 44 eco-races of tasar silkworms reported from 17 states of India (Mathur *et al.*, 2005). The common eco- races are Sarihan, Daba, Sukinda, Modal and Jata–Daba. The tasar silkworms are cultivated *ex-situ* in natural forests, however, some attempts have been made for its semi domestication.

Effect of photoperiod on development, particularly induction and termination of diapause in the Saturniid pupae has been extensively studied (Fukunda, 1953; Danilevskii, 1965; Jolly *et al.,* 1971; Suryanarayana and Srivastava, 2005). Besides diapause, the photoperiod is also known to determine optimum time regime during a day cycle for the moth emergence, coupling, egg laying and hatching in tasar silkworms (Jolly *et al.,* 1971). Tasar silkworms being voracious herbivore are essentially an integral part of the forest ecosystem. However, the utilization of leaves of the food plants by tasar larvae does not change the floral and faunal diversity. There is paucity of information on the prevalence of phenotypic and behavioural traits of eco-races of tasar silkworms in this region. However, no systematic account is available on the taxonomic characterization of different instars of silkworms prevalent in the region. Considering these facts in mind, the present study has been undertaken. The objective of the present study is to provide information on the phenotypic and behavioural traits and taxonomic characterization of these tasar silkworm ecoraces of the region in order to know their overall performance needed in their domestication.

MATERIALS AND METHODS

The eco-races were collected from the region of the Bihar, Jharkhand and Orissa which were reared for three crops in a year in 2009. The third crop harvested cocoons were preserved, and these cocoons were used for the first grainage in 2010. Moreover, at each study site environmental parameters were recorded daily viz. temperature, humidity, rainfall, duration of sunshine and day length. The air temperature was measured with the help of a maximum and minimum thermometer placed inside a Stevenson screen at 1.3 m above ground level. The humidity was measured with the help of a hygrometer. The rainfall was measured by a raingauge erected on 0.6´0.6´0.6 m concrete foundation. The duration of sunshine recorder was erected on a solid masonary pillar at a height of 3 meters above the ground level. The day length was calculated from the timing of sunset and sunrise which were related to the visibility of the upper beam of the sun on the horizon. The study was made during all the three generations of these eco-races of tasar silkworms. Meteorological data were collected regularly for the entire study period. The taxonomical diversity of eco-races has been noted apart with the morphometrics stages of the life cycle of the silkworms.

RESULTS

The eco-races are Sarihan, Daba, Sukinda, Modal and Jata-Daba respectively. The taxonomic diversity of eco-races of tasar silkworms has been depicted in Table 1. The environmental conditions controlling the survival and propagation of these eco-races are presented in Table 2. The optimum ranges of these physical factors for these races are summarized in Table 3. The leaf requirement of arjun (*Terminalia arjuna*) for different life cycle stages of eco-races are shown in Table 4 indicating maximum utilization in last instar larval stage.

The comparative study of crop performances has been studied and found that winter crop was much productive in terms of rearing, shell weight and silk yield (Table 5 and 6). Table 3 showed the optimum temperature required for rearing of healthy growth of silkworm. In Table 4 the total amount of food material required for healthy growth of 500 DFLs of tasar silkworm. In Table 5 and 6 the Daba ecorace had strength to pull up 81.90g silk yield in winter and so as the lowest production of silk yield 75.44g in rainy season. The Sukinda have the capacity of lowest silk yield.

It was investigated that for the voltinism the optimum temperature ranged between (24 $\pm$ 2 to 28 $\pm$ 2ºC) and relative humidity (74 $\pm$ 2 to 88 $\pm$ 2%) respectively have been recorded. The ecoraces Sarihan, Daba, Jata-Daba, Sukinda and Modal were taken into account and their cocoon weight of 8.414g, 11.306g, 13.569g, 11.72g and 15.561g were

Table 1: Taxonomical diversity of eco-races of tasar silkworms

Ecoraces	Sarihan	Daba	Jata-Daba	Sukinda	Modal
Food plants	*Terminalia* sp.	*Terminalia* sp	*Terminalia* sp	*Terminalia* sp	*Shorea robusta*
Voltinism	Bivoltinism	Trivoltinism	Bivoltinism	Trivoltinism	Uni/Bivoltinism
Cocoon colour	Yellow grey	Light grey	Yellow grey	Yellow	Blackish grey
Peduncle length (cm)	6.06	4.49	6.15	6.36	6.50
Cocoon wt (g)	8.414	11.306	13.569	11.720	15.561
Shell wt.(g)	1.266	1.874	2.311	1.364	3.226
Length × breadth (cm)	4.31×2.72	5.12×3.14	5.33×3.33	4.90×3.01	5.36×3.49
Reelability (%)	70.0	73.0	72.0	62.0	63.0

Table 2: Environmental conditions for rearing of silkworm

Year 2009-2010	Temperature (ºC)		Relative humidity (%)		Rain fall (mm)	Wind speed (km/h)
	Max.	Min	Max.	Min		
June 2009	36.9	26.1	79	53	63.9	6.5
July	33.0	26.1	91	72	281.1	7.0
August	32.5	25.7	93	76	361.2	6.2
September	33.4	25.4	90	72	126	4.8
October	31.3	20.0	91	63	154.1	3.4
November	27.8	15.0	93	56	2.7	2.9
December	24.1	9.1	96	50	0.0	2.4
January 2010	18.7	6.8	97.6	64.8	0.0	5.7
February	26.1	10.4	90.0	44.2	5.2	3.9
March	33.5	16.4	76.9	35.4	6.2	4.5
April	38.5	21.9	72.9	37.7	8.1	6.9
May	36.8	24.2	77.6	47.6	60.2	8.4

Table 3: The optimum environmental conditions for rearing of tasar silkworm

S. No.	Stage	Temperature (ºC)	Humidity (%)	Rain fall (mm)	
				Winter (Oct-Dec.)	Rainy (July-Sep.)
1	1st Instar	26-28	80-90	88.97	251.29
2	2nd Instar	26-28	84-90	86.57	240.45
3	3rd Instar	25-26	80-85	85.43	232.89
4	4th Instar	24-25	72-75	82.32	225.94
5	5th Instar	23-24	70-72	80.21	206.89

Table 4: Leaf requirement (about 500 eggs per DFL's) by different instars of silkworms

S. No.	Silkworm Stage	Quantity of arjun leaf required (approx.) (kg)
1	1st Instar	3-5
2	2nd Instar	6-10
3	3rd Instar	35-45
4	4th Instar	85-100
5	5th Instar	600-700

Table 5: The tasar crop performance in winter season (Sep – Dec)

Ecorace	Fecundity (No)	Hatching (%)	Larval wt.(g)	Effective rate of rearing (%)	Shell wt.(g) of rearing	Silk yield (g)
Daba	337	50.1	14.56	19.9	1.67	81.9
Jata-Daba	309	51.6	13.23	19.8	1.50	79.20
Sarihan	295	54.5	12.11	19.10	1.42	70.20
Sukinda	286	54.3	12.00	26.21	1.36	60.54
Modal	260	71.2	12.43	29.34	1.38	81.93

Table 6: The tasar crop performance in rainy season (July– August)

Ecorace	Fecundity (No)	Hatching (%)	Larval wt.(g)	Effective rate of rearing (%)	Shell wt.(g) of rearing	Silk yield (g)
Daba	311	51.75	11.86	17.50	1.37	75.44
Jata-Daba	280	53.38	9.98	17.32	1.27	70.24
Sarihan	275	52.63	8.76	17.23	1.09	63.42
Sukinda	262	71.56	8.13	23.20	0.98	62.10
Modal	234	78.93	9.26	24.82	1.08	71.71

recorded respectively and shell weight of these eco–races were observed in Sarihan (1.266g), Daba (1.874g), Jata Daba (2.311g), Sukinda (1.364g), and Modal (3.226g) respectively. The eco-race Sarihan has lowest cocoon weight, shell weight and volume but the highest measurement observed in Modal race.

Therefore, it is suggested that the Daba race will be cultivated in normal environment and produce more reliability of silk yield, which is beneficial for their commercialization as a cottage industry for its sustainable development.

DISCUSSION

Antherea mylita Drury is a polyphagous insect and semi-domesticated tasar silkworm feeding on *Terminalia* species and sal (*Shorea robusta*). The eco-races are bivoltine or trivoltine, depending upon the voltinism of the races, the reproduction concide with rain (July-August) and winter (September-December) seasons. There is differentiation of commercial characters of eco-races of tropical tasar silkworms. The populations of these ecoraces are declining alarmingly in their natural habitat due to rapid deforestation, rampant collection of wild cocoons and pollution. Suryanarayana and Srivastava (2005) observed that population of these silkworms was under threat but their conservation into *in situ* condition was not possible. The only way to conserve the original population was through *ex situ* conservation. It may be also possible to locate areas, other than natural habitats, where these eco-races shall be conserved and multiplied through *ex situ* conservation.

In silkworms the poor quality and productivity of silk could be attributed to high temperature and low humidity conditions which was a characteristic of tropical climatic conditions. Effect of various exogenous factors such as photoperiod, starvation and food plant plays the critical role in the development of the eco-race of tropical silkworms. The voltinism and seasonal polymorphism are controlled by environmental factors such as temperature and photoperiod (Danilevskii, 1965). However, more information is available on the characterization of voltinism in *Bombyx mori* and shows its relationship with environmental factors (Fukunda, 1953). In *Antherea mylita* species the occurrence of voltinism and the effect of temperature and photoperiod was reported by Mansingh and SmallMan (1967), which is in conformity with our observation.

In the present study the critical range of humidity, temperature and rainfall for last instar stage of these eco-races were much lower than the earlier instars.

The physical factors viz. temperature, humidity, rainfall, photoperiod affect the biology and voltinism of silkworms. The effects of physical factors produce a new scope of voltinism manipulation for increasing silk productivity. The poor quality and productivity of races could be attributed to high temperature, low humidity condition and characteristic of tropical climatic conditions. The combination of abiotic and biotic factors affect the diversity of ecoraces of tasar silkworms. The result showed the resultant contribution of altitude, minimum and maximum temperature, photoperiod and larval duration which affect the commercial characters like cocoon wt, larval period and silk ratio. The low temperature reflects the lower number of life cycle in a year. Based on this observation, the crops of tasar silkworm get divided into univoltine, bivoltine and trivoltine. The relatively lesser rainfall during commercial crop season (Sep-Dec) than the seed crop season (July-August) may contribute the evident changes in the dietary content of leaves to raise the difference of the phenotypic and behavioural traits of ecoraces. A combination of suitable ecological factors viz. mature quality of leaf, temperature range (28°C), 16 h photoperiod and 80% RH were being subjected to normal rearing of the larvae during seed crop and commercial crop seasons respectively. The variations in these eco-races were caused by temperature, relative humidity, photoperiod, day length, sunshine and rainfall. The traits taken into consideration were cocoon colour, volume, weight, fecundity, hatchability, shell weight and absolute silk yield.

In Bihar and Jharkhand *A. mylita* has been reared on Arjun and Asan host plants and exhibits bivoltinism and trivoltinism in two ecoraces Daba and Sarihan respectively. These ecoraces are significantly different in phenotypic characters (traits) in terms of fecundity, cocoon weight, shell weight, absolute silk yield and filament length. Srivastava *et al.* (2004) indicated that environmental conditions have great bearing on phenotypic traits of *A.mylita* and variability caused by environmental conditions has serious implication in selecting genetic variability. It has more reliability among other, so may be more beneficial and suggested exploitation for cottage industry. It has been emphasized that much of the silkworm genetic diversity is derived from the instead lines of land races and also from hybridization of different geographical races. The genetic erosion of these silkworm races over the period is due to biotic and abiotic stresses caused to the organisms enclaved through adaptation, indiscriminate use of bio-resources, destruction of forest, human interference in ecosystem and damage to the environment (Sengupta *et al*., 1987). It may be attributed that non-adoption of sustainable harvesting technique by the stock holders has natural imbalance in the multiplication process. Hence, there is an urgent need of community participation in the conservation of native tasar ecoraces. The principle of equality, participation, community building co-operation and integration enable people to manage plan, regulate and enforce those of the semi resources in their specific areas.

Seasonal effect of tasar silk production

The bivoltine tasar insect has two annual life cycles; I. seed crop (July-August) with shorter larval span yielding non-diapausing cocoons with thin shell and simultaneous moth emergence followed by egg laying and II. Commercial crop (September-December) is with longer larval span, yielding cocoons with thicker shell undergo prolonged pupal diapause of 6 - 7months (Suryanarayana and Srivastava, 2005). The potential phenotypic expression of a genotype desires suitable environment (Sengupta *et al.,* 1987; Srivastava *et al*., 2004) and the environment being exogenic factor, it influences the expressivity of gene by generating different phenotypes under different environmental regime (Zhao *et al*., 2007). The variations in climate, nutrient status, feeding duration and larval crowd along with environmental stimuli will influence the insect body size (Davidowitz *et al*., 2004; Miller, 2005).

Miller (2005), Chandrasekhar and Basavaraja (2008) and Reddy *et al*. (2009) have reported that the environmental conditions of different rearing seasons also have its influence on expression of parental combinations. The environmental role can be explained through the cocoons with thin shell and low silk yield observed during seed crop (July/August) and thick shell and high silk during commercial crop (September/December) seasons, which also signifies their role in seed and silk production. Hence, for the commercial crop season (Sep-Dec: with temperature of 17-28°C and RH of 60-80%), selection of quantitative traits like shell weight, silk ratio and silk yield should be emphasized so as to achieve longer filament, while during seed crop season (Jul-Aug: with temperature of 23-35°C and RH of 45-75%), the priority should be on fecundity and egg hatching to achieve higher cocoon yield to support the planned commercial seed production. The tested parental combinations have shown their contribution for both seed and commercial crop rearing seasons by expressing increase in fecundity and shell weights and to finally enlarge the silk yield.

The selection of bigger females improves silkworm fecundity and parents with higher shell will contribute better shell weight and silk ratios (Chandrasekhar and Basavaraja, 2008; Reddy *et al*., 2010).

The tasar silkworm is an eco-insect and its low performance in captivity against potential both during silkworm rearing (cocoon production) and grainage activity (seed production), denote its intricate behaviour. Though, the region enjoys the availability and practice of mulberry, tasar (tropical/temperate) silks, the utilization of tropical tasar seri-biodiversity, however, requires appropriate breeding methods so to exploit the global demand of this wild silk, besides reforming tribals, weaker sections and landless rural population on economic front. Among the existing 44 ecoraces of *Antheraea mylitta* Drury, only Daba and Sukinda are commercially applied for cocoon production and the urgent need is *in situ* conservation and *ex situ* stabilization of additional ecoraces (Mathur *et. al.,* 2005).

The critical areas of silkworm rearing from egg incubation to spinning of cocoon needs appropriate handling to convert maximum number of viable silkworm eggs to quality silk cocoons. Though, the technologies for tasar silkworm rearing are available, their adoptability and commercial feasibility among rearing groups and operational areas require fine-tuning and the field functionaries need some modifications for better silk production. The fine-tuned adoptable technologies for higher egg hatching and healthy larval population, control of diseases and larval mortality and minimizing the cocoon yield loss with pests and predators, requires wider publicity among end users, appropriate advocation of specified methodology and in-time adoption for attainable productivity, quality and economic success in tropical tasar silkworm rearing. However, the commercial sustenance of this forest based activity needs practical and potential utilization of biodiversity to meet the fast changing human needs besides, conserving the environment and ecological integrity.

CONCLUSION

On comparative basis the tasar crop performance in commercial winter season gave the higher cocoon and silk yield than the seed crop of rainy season. In general, the commercial rearing of tasar silkworm aims for higher cocoon yields, which has overall impact on the success of the industry, as this leads to the tasar silk and seed cycle and land based employment to local people. The more tasar silk performances in winter is solely contributed by congenial physical factors prevailing in this season.

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