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Effect of rearing seasons and food plant combinations on economic traits of cocoons and yarn of Muga silkworm (*Antheraea assamensis* Helfer)

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ABSTRACT

Muga silkworm, *Antheraea assamensis* Helfer (Lepidoptera: Saturniidae) is a multi-voltine polyphagous insect which produces golden yellow muga silk. Muga silkworm feeds on leaves of many tree plant species but primarily the leaves of *Persea bombycina* Kost. (Som) and *Litsea monopetala* Roxb. (Soalu). The farmers rear the silkworm mainly in two seasons for commercial purposes although the silkworm can be reared six times (crops) in a year. Productivity of silkworm rearing is dependent on cocoons and yarn characteristics which are affected by the type of food plants at the time of rearing. In this study, an attempt was made to evaluate the economic characters of cocoons and yarn of muga silkworm reared in different combination of primary food plants in different seasons. Two primary food plants *P. bombycina* and *L. monopetala* were selected in four combinations (T1 –T4) for rearing in two commercial crop seasons namely *Kotia* (V1), *Jethua* (V2) and two seed crop i.e. *Bhodia* (V3) and *Chotua* (V4). Cocoon weight and pupal weight were higher in the cocoons harvested from the silkworm reared in *L. monopetala* only and mainly in Kotia (October-November) seasons followed by *Jethua* (April-May), *Bhodia* (August-September) and *Chotua* (February-March) seasons. Shell weight, shell ratio, filament weight, filament length and non-breakable filament length (NBFL) were higher in the silkworms reared in *P. bombycina* (T1) irrespective of seasons followed by treatment combination T4 (*L. monopetala* up to 3rd instar then *P. bombycina)*. Benefit cost ratio (BCR) was higher in T1 combination during *Kotia* (10.61:1) seasons followed by *Jethua*, *Bhodia* and *Chotua* crop seasons. As such, *P. bombycina* is the preferred food plant for commercial rearing of muga silkworm, however the silkworm can be reared in *L. monopetala* up to 3rd instar and thereafter in *P. bombycina* till maturation for higher productivity in terms of cocoon and yarn characteristics.

Key words: *Muga silkworm, Food plants, Cocoons and yarn characteristics, Rearing seasons.*

Introduction

Muga silkworm (*Antheraea assamensis* Helfer) is reared for production of reeling cocoons to produce golden yellow silk, which is the costliest among all the commercially available silk in the world. Assam is the only place in the world where all commercial exploited varieties of silk are produced (Hazarika *et al*., 1995). During 2018-19, the contribution of muga silk was 231.8 MT in India (Annual Report, Central Silk Board). The golden yellow muga silk of Assam is the sole product of India and no-where in the world, the silkworm is available due to peculiar insect behavioural adaptation and requisite climatic condition (Ahmed and Rajan, 2010). Muga culture has been practised by about 44,000 families in the different states of North Eastern region out of which, Brahmaputra valley of Assam is the main production zone and contributes about 83.74% of India's total muga silk production (Basu, 1915; Choudhury, 1982).

The silkworms feed primary two food plants i.e. *Persea bombycina* Kost (Som) and *Litsea monopetala* Roxb. (Soalu). These two food plants are abundant in the plains and hills of the North Eastern region. Although many are food plants of muga silkworm were reported previously, only *P. bombycina* plantations are available for commercial rearing in most of the farmer's field (Devi *et al.,* 2021). The silkworm has six broods in a year and those were named based on the rearing seasons namely *Jethua* (April-May), *Aherua* (June-July), *Bhodi*a (August-September), *Kotia* (October-November) and *Jarua* (December- January) and *Chotua* (February-March). Out of these, only two broods *viz*. Jethua and Kotia are reared for commercial purposes. The other broods are raised as seed and pre-seed crops.

The success of silkworm farming is primarily reliant on the leaf quality and favourable environmental conditions during the time of rearing (Devi et al, 2021). Leaf constituents are the sole source of nourishment as the plant protein consumed gets transformed into silk protein. The survivability of worms as well as harvesting of ripened worms depend on several factors, out of which, host plant has the major role. According to Choudhury (1992), relative contribution of such factors responsible for a successful crop harvest was estimated as host plant (38.2%), climate (37.0%), rearing technique (9.3%), silkworm race (4.2%), silkworm egg (3.1%) and other factors (8.2%).

The nutritive value of host plants and their seasonal variability are closely related to that of the silk worm. The host plant nutrition and their seasonal variations affect growth and development of silkworm and their cocoons quality (Devi *et al.,* 2021). The success of muga culture mainly depends on the accessibility of food plant and their leaf nutritional status, as the consequent silkworm rearing on them could result to a higher number of cocoons or the cocoons of superior quality in terms of pupation or silk content. In view of the fact that quality of foliage has a persuade on the growth and development of muga silkworm, selection of the food plants possessing superior nutritive value is of great importance for the healthy development of silkworm and in obtaining quality cocoon crops (Dutta *et al.,* 1996).

The food plant varietal effect of Muga silkworm is very much important. The quality of feed plays a remarkable role on the growth and development of the silkworm and ultimately on the economic traits of cocoons (Maribashetty *et al*., 1999). The nutritional status of the leaves of the different plants varies in the different seasons. Bindroo *et al*., (2006) observed that the Som leaves were ideal during autumn while Soalu leaves were suitable in the late spring for rearing the muga silkworm. From the above review, it is clear that effect of host plant on performance of muga silkworm rearing and grainage has not been vividly reported for all possible host plant/combination in all rearing and grainage seasons. Hence, the present study is undertaken to make a comparative evaluation of the primary host plants alone and in combination through bioassay studies. In the present research work, an attempt to compare the post cocoon parameters of muga silkworm on two different host plants and post cocoon parameters.

Materials and Methods

Experimental site and location

The investigation was carried out at P2 farm, Dhupguri, Boko, Kamrup, Assam (Coordinates: 25.97777°N 91.23557°E). The trial was set in fairly uniform topography and well-drained soil which had homogenous fertility and textural composition and was well connected with irrigation facilities for regular and timely irrigation as per necessity.

Selection of host plant and silkworm rearing

Two host plants *i.e*. Som (*Persea bombycina*) and Soalu (*Litsea monopetala*) of same age (10 years) were selected for the study. The disease free laying (dfls) of muga silkworm were obtained season wise from Muga Eri Silkworm Seed Organization, Central Silk Board, Guwahati for conducting the experiments. A total of 1000 worms were brushed in *P. bombycina* tender leaves as rearing stock -1 and another 1000 worms were bushed in *L. monopetala* tender leaves as rearing stock -2. When the worms attained 3rd stage, 300 worms from stock-1 transferred to *P. bombycina* as control (T1) and continued up to maturation. Likewise 300 nos of 3rd stage worms from Stock-2 were transferred to *L. monopetala* as control (T2) continued up to maturation. Another 300 worms of 3rd instar from stock-1 transferred to *L. monopetala* and fed up to maturation as treatment (T3). Likewise 300 worms of 3rd instar worms from stock-2 transferred to *P. bombycina* and fed up to maturation as treatment (T4). Each treatment was conducted with 3 replications. Silkworm rearing was conducted in two commercial crop namely V1, Kotia (October-November) and V2 Jethua (April-May) and two seed crop – V3, Bhodia (August-September) and V4, Chotua (February-March). Rearing parameters and performances like larval weight, duration, effective rate of rearing etc. were recorded in each crop and calculated.

Post cocoon parameters

After maturation cocoons were collected for evaluation. For evaluation of post cocoon parameters, 10 nos of cocoons were selected randomly and measured the cocoon weight (g). Shell weight was taken after removing the pupa from the cocoons. Shell ratio (%) of cocoon was calculated by the formula, Shell ratio (%) = Shell weight (gm) × 100 / Cocoon weight (gm)

Further, cocoons were degummed using sodium carbonate and neutral soap followed by reeling using Epprouvette. Filament was withdrawn from single cocoon in semi moist condition and breaks were noted during reeling. The total length of yarn from single cocoon was estimated by multiplying the number of revolution (noted from revolution counter meter) with factor of 1.125. Yarn was collected for each observation. After drying, yarn weight was measured using a precision electronic balance. Yarn denier and NBFL were estimated by the following expression:

Yarn denier = Filament weight (g) × 9000 / Yarn length (m)

Non-broken filament length (NBFL) (m) = Filament length/ No of cocoons + no of breaks

For single cocoon, Non-broken filament length (NBFL) (m) = Filament length/ 1 + no of breaks

Benefit-cost ratio

Covering cost involved in the silkworm rearing in one acre land, cost benefit ratio (B: C) was calculated in all the seasons against all the treatment. Rearing cost (27713) per acre was calculated covering all the input cost (details not shown), cocoons required for 1 kg of raw silk was calculated based on the average filament weight of the cocoons under different treatments. The cocoons production per acre of plantation in a year is calculated based on the average norms of Central Silk Board which is 60000 cocoons in commercial seasons (V1 and V2) and 40000 in seed crop seasons (V3 and V4).

Statistical analysis

For determining the significance of differences between the treatments and to draw accurate conclusions, the data taken were subjected to statistical analysis by 'Analysis of Variance' for split plot design and the significance was tested by ''Variance ratio'' i.e. 'F' value (Gomez and Gomez, 1984). The standard error of mean (S. Em. ±) and critical difference (CD) were worked out for each character examined to evaluate the difference between the treatments and interaction effects at 5 % level.

Results

Cocoon characteristics

Cocoon weight, shell weight and shell ratio in different treatment and different seasons were measured to evaluate the comparative performance economic traits in different treatment combinations. Cocoons weight were maximum (5.15±0.2g) in the treatment T2 during *Kotia* (V1) crop, which was observed in all other seasons. As such Kotia (Oct-Nov) is the most suitable seasons for muga silkworm rearing in *L. monopetala* plant. Further, rearing treatment T1 (*P. bombycina* only) was comparatively superior in terms of cocoon weight followed by T3 and T4 respectively (Fig. 1). *Chotua* crop (February – March) recorded significantly lowest cocoon weight (4.14g) which is not profitable for silkworm rearing.

Shell weight was also influenced significantly by

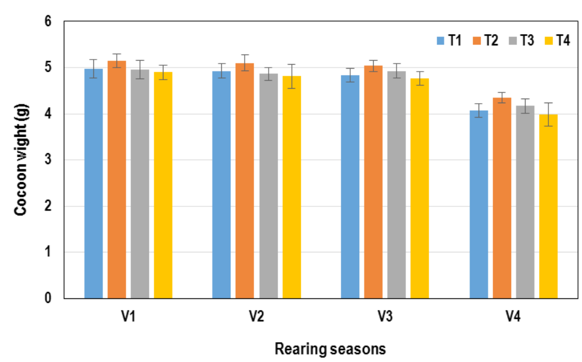

Fig. 1. Effect of food plant combinations on cocoon weight of muga silkworms reared during four different rearing seasons (2016-2018)

host plant combinations during different rearing seasons (crops). Among the rearing seasons, higher shell weight (0.51g) was also recorded in *Kotia* crop followed by *Jethua* (5.1g), *Bhodia* (0.5 g) and *Chatua* (0.44g) crop when the silkworm were reared in *P. bombycina* (T1). There were significant different on cocoon shell weight when silkworms were reared in different seasons. Shell weight were always higher during commercial seasons and better when reared in *P. bombycina* in all the cases (Fig. 2). As such, host plants and silkworm rearing seasons had significant effect on cocoon shell weight of muga silkworm.

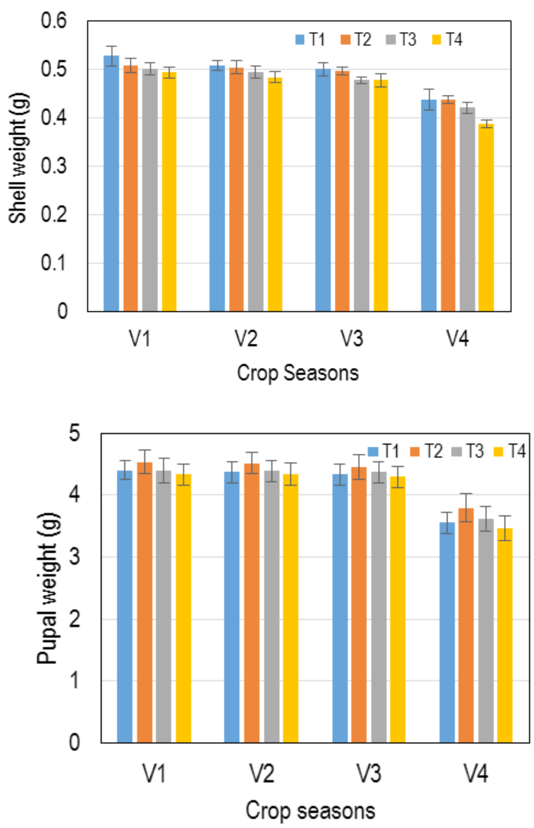

Fig. 2. Effect of food plant combinations on cocoon shell and pupal weight of muga silkworms reared during four different rearing seasons (2016-2018)

Likewise, pupal weight (g) was also influenced by the host plant and their combinations and rearing seasons significantly during the study. Among the rearing seasons, pupal weight were significantly higher in the cocoons reared during *Kotia* (4.42g) compared to *Bhodia* (4.4g) and *Chotua* crops (3.6g). However, no significant difference was observed in pupal weight of *Jehtua* and *Kotia* rearing seasons (Fig. 2). But, pupal weight was higher in all the cocoons reared in *L. monopetala* plants irrespective of the seasons.

Yarn characteristics

Economic characters of the muga silkworm are normally measured in terms of yarn or filament weight, filament length including non NBFL and denier. During the experiment, significant differences were observed in filament weight, filament length and denier of muga when the silkworms were reared in different treatment. Highest recovery of filament length (420.7m) and NBFL (176.7m) were obtained when the silkworms were reared served in *P. bombycina* irrespective of the rearing crop seasons (Fig. 3). Further, host plant combination T4 were better than the T2 (*L. monopetala*) and T3 (up to 3rd instar *P. bombycina* then *L. monopetala).* Differences were significant in all the treatment combination and affected by the rearing seasons.

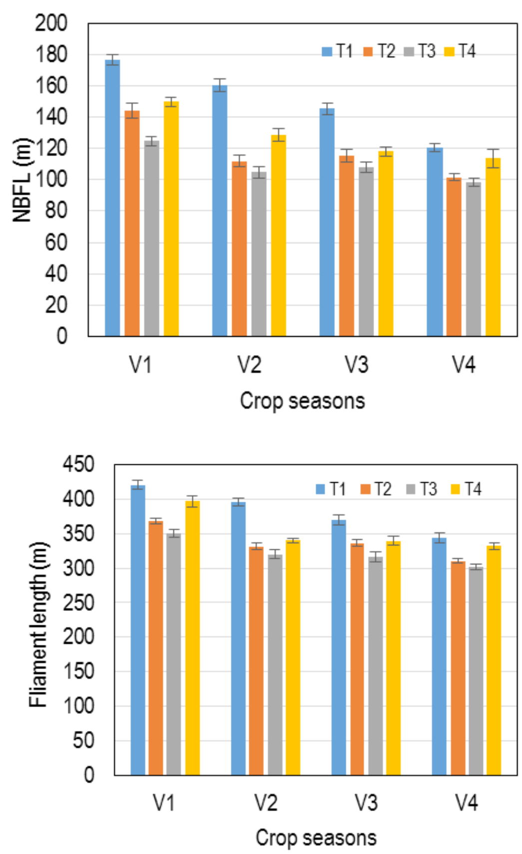

Fig. 3. Effect of food plant combinations on filament length and NBLF of muga silkworms reared during four different rearing seasons (2016-2018)

Among the different rearing seasons, *Kotia* (0.18g) was recorded significantly superior in terms of filament weight recorded during the study. Weight of the filament eventually impacts on total raw silk production from the cocoons produced. As such, rearing during the *Kotia* season in *P. bombycina* is superior irrespective of the seasons (Fig. 3). Filament weight was also higher in *Jethua* (0.172g) and *Bhodia* (0.17) and less in *Chatua* (0.15g).

Likewise, filament denier was also higher in *P. bombycina* reared cocoons in Kotia (4.56) seasons followed by *Jethua* (4.24), *Bhodia* (4.17) and *Chatua* (3.96) seasons. If host plant is only considered rearing in *P. bombycina* was always better. However, silkworm rearing in *L. monopetala* up to 3rd instars then in *P. bombycina* up to maturation (T4) is a superior combination for getting higher denier irrespective of the seasons, if *P. bombycina* are not available exclusively for conducting the rearing.

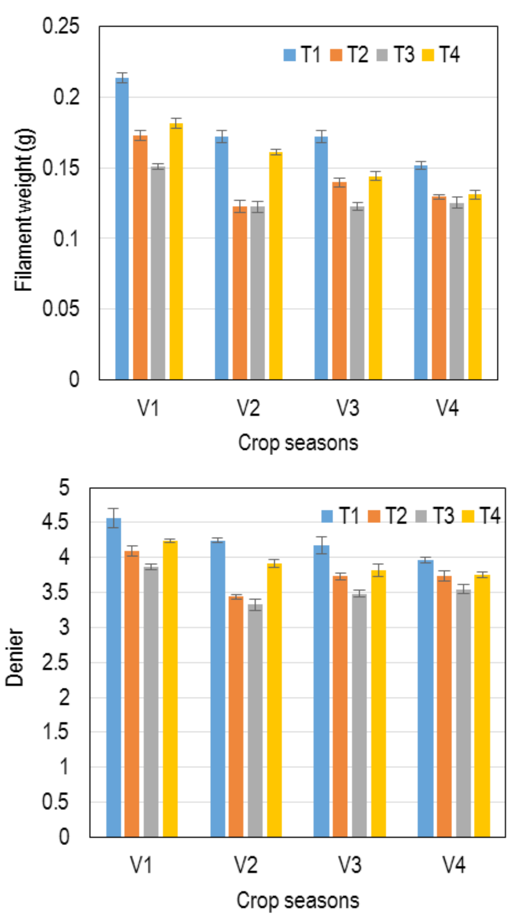

Fig. 4. Effect of food plant combinations on filament weight and Denier of muga silkworms reared during four different rearing seasons (2016-2018)

Benefit-Cost (BCR) ratio

Silkworm searing input cost during all the rearing seasons and host plants were calculated previously. After considering the input cost, cocoon produced till yarn production (raw silk) and selling in prevailing market rate, the benefit-cost ratio (BCR) in different treatment combinations in all the seasons were assessed. Maximum gross return was obtained from *Kotia* crop (T1) with highest BRC (10.61:1) followed by *Jethua* (8.57:1) and *Bhodia* (5.71:1) seasons. BCR was recorded higher in T1 combination followed by T4, T2 and T3 respectively irrespective of the seasons (Table 1).

Discussions

Productivity of silkworm farming is mainly depend on food plant and rearing season (Pillai *et al.*, 1987; Lindroth and Hemming, 1990). Food plant nutrition effect on good cocoon quality, shell weight and shell ratio (Sinha *et al.*, 1986; Siddiqui *et al.*, 2006). In the present investigation, it was observed that rearing during *Kotia* (October – November) crop significantly maximum filament length, NBFL, filament weight, filament denier were recorded compared to *Chotua* (February – March) and *Bhodia* (August – September). While, Jethua (April – May) season was recorded statistically at par with *Kotia* (V1). However, *P. bombycina* was a better for commercial rearing while for seed crop rearing *L. monopetala* was suitable during this season (Battacharya and Bindroo, 2007; Kakati, 2012; Tikader, 2012). In Bhodia crop, rearing on *L. monopetala* revealed higher cocoon weight but shell weight was in *P. bombycina*. During this season also, it was found that rearing on *L. monopetala* was suitable for seed crop. Dash *et al.* (2012) has also made similar observations were in came of *A. mylitta* reared on different forestry host plants viz., *Terminalia alata, T. arjuna, Shorea robusta, L. parviflora, T. bellirica,* and *S. cumini* in rainy season at lower, medium, and higher altitudes in Odisha.

The quality of the leaves has a significant effect on superiority of silk produced by the silkworm. Leaves of superior quality enhance the chances of good cocoon crop (Ravikumar, 1988). The quality of feed plays a remarkable role for growth and development of the silkworm and ultimately on the economic traits of cocoons (Hazarika *et al.*, 2003; Gangwar, 2010; Kumar and Vadamalai, 2010). In

Table. Benefit-cost ratio of silkworm rearing in different seasons with different host plant combinations

Crop (Season)	Treatment	Cocoons per acre/ year	Filament weight (g)	Rearing cost/acre /year (Rs)	Cocoons required for 1 kg raw silk	Raw silk (kg)	Income Rs.in lakh (@0.23/kg)	BCR
Kotia (Sept -Oct)	T1	60000	0.213	27713	4695	12.78	2.94	10.61
	T2	60000	0.173	27713	5780	10.38	2.39	8.62
	T3	60000	0.151	27713	6623	9.06	2.08	7.52
	T4	60000	0.181	27713	5525	10.86	2.50	9.01
Jethua (April-May)	T1	60000	0.172	27713	5814	10.32	2.37	8.57
	T2	60000	0.123	27713	8130	7.38	1.70	6.13
	T3	60000	0.122	27713	8197	7.32	1.68	6.08
	T4	60000	0.161	27713	6211	9.66	2.22	8.02
Bhodia (Aug-Sept)	T1	40000	0.172	27713	5814	6.88	1.58	5.71
	T2	40000	0.141	27713	7092	5.64	1.30	4.68
	T3	40000	0.123	27713	8130	4.92	1.13	4.08
	T4	40000	0.144	27713	6944	5.76	1.32	4.78
Chotua (Feb-March)	T1	40000	0.152	27713	6579	6.08	1.40	5.05
	T2	40000	0.129	27713	7752	5.16	1.17	4.28
	T3	40000	0.125	27713	8000	5.00	1.15	4.15
	T4	40000	0.131	27713	7634	5.24	1.21	4.35

muga silkworm also, nutrition plays an important role in improving the growth and development of the silkworm. The rearing on *L. monopetala* showed higher cocoon weight than *P. bombycina* while in silk quality, cocoons from *P. bombycina* exhibited superior quality (Saikia *et al*., 2004). Chakrovorty *et al* (2004) reported higher weight of first and second instar larvae fed on *L. monopetala* than that of the larvae fed on *P. bombycina* and *L. salicifolia* while higher moulting percentage was observed in first and second instar larvae fed on *P. bombycina*. In the present study, it was observed higher cocoon weight in *L. monopetala*, while shell ratio was significantly higher in *P. bombycina* in most of the seasons. Reddy *et al.* (1989) studied pupal weight, cocoon yield, shell ratio and reproduction of *Samia ricini* on castor, tapioca, *Plumeria* and *Ailanthus* and observed significant variation.

Highest filament length, NBFL, filament weight, filament denier was found under *P. bombycina* (1^{st} to 5^{th}) compared to the rest of the treatment. Muga silkworm rearing in food plant combinations i.e. *L. monopetala* (1^{st} to 3^{rd}) + *P. bombycina* (4^{th} to 5^{th}) recorded highest filament length after solely rearing in *P. bombycina* which was significantly superior from the treatment T_2 and T_3. When the silkworm was fed exclusively with *P. bombycina* (T_1), it gave better performance in terms of shell ratio in both *Kotia* and *Jethua* commercial crops ($T_{1,2,3}$). In case of commercial crop, shell ratio percentage assumes greater importance. The present investigation suggests that in case of commercial crop, if leaf shortage is occurred, when muga silkworm rearing is done exclusively with *P. bombycina*, the rearing may be shifted to *L. monopetala* plantations. Present investigation suggested that performance of SR% was better in T_3 after T_1 when Muga silkworm fed with *P. bombycina* leaves up to first three instars followed by *L. monopetala* leaves (T_3).

Since, the cocoon and yarn characteristics varied in different treatment (food plant) combination, it also effected in total raw silk production per unit area. Hence the benefit cost ratios were also different. As all the post cocoon performances were higher in *Kotia* crops, BCR were also higher. As such farmers prefer *P. bombycina* for rearingof muga silkworm during *Kotia* seasons and it the plants are not sufficient, they may rear silkworms in *L. monopetala* up to 3^{rd} instar and thereafter transfer to *P. bombycina* to completet the rearing in order to increase the crop productivity.

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