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Effect of Sole and Combination of Food Plants on Degumming of Cocoon and Physical Properties of eri (*Samia ricini* Donovan) Silk Yarn

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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

The study revealed that castor fed worms registered for maximum yarn yield and size with minimum degumming loss and degumming period followed by kesseru fed worms. Though borpat fed worms registered lower values in respect of yarn yield with higher degumming loss and longer degumming period, the food plants had no significant effect on physical properties of the yarns *viz*, breaking load, tenacity, elongation percentage and imperfection. Interchange of food plants was found to have a decreasing trend in yarn yield and yarn size than sole food plants, however, there was no significant difference among the interchange combinations of food plants in respect of yarn yield and physical properties of the yarns *viz.*, tenacity, elongation and imperfection.

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Keywords: Degumming loss; degumming period; elongation; imperfection; Samia ricini; tenacity; yarn yield and yarn size.

1. INTRODUCTION

Sericulture is defined as the rearing of silkworm to obtain silk filament. It represents labour intensive, low-investment, small scale industry that caters to both marginal and small landholders due to its potential for high returns, short gestation period and year round employment opportunities for family members. Farmers are engaged in various activities like silkworm host plant cultivation, seed production, silkworm rearing to produce silk cocoons, reeling the cocoons to unwind the silk filament, yarn manufacturing, weaving and fabric preparation from silk [1,2]. Sericulture is broadly classified into two distinct sectors *viz*., mulberry and *vanya*. Mulberry sericulture is concerned with rearing of mulberry (*Bombyx mori*) silkworm for production of mulberry silk and *vanya or wild* sericulture is concerned with rearing of different wild silkworms *i.e.* eri (*Samia ricini* Donovan), muga (*Antheraea assamensis* Helfer), tropical tasar (*Antheraea mylitta* Drury) and oak-tasar (*Antheraea proylei* Jolly) for production of eri, muga and tasar silk respectively.

Among the various vanya silkworms, the eri silkworm is reared under indoor conditions and the silk produced is often referred to as the *Ahimsa silk* or the fabric of peace. The name *Ahimsa silk* is derived from the fact that eri cocoon consist of discontinuous filament and hence the processof unwinding the silk filament does not involve the killing of the silkworm.The word “Ericulture’’ has been derived from the Sanskrit term “eranda” which refers to the castor plant (*Ricinus communis*), the primary host plant of eri silkworm which is also known as “era” in Assam. Ericulture is basically a house hold activity and plays a significant role in the socio-economic condition of the people of the North Eastern India from the time immemorial. The culture is mainly confined to the Brahmaputra valley of Assam and in the tribal inhabitated districts of neighboring states namely, Meghalaya, Nagaland, Manipur and Arunachal Pradesh. Now-a-days, eri culture is spreading in different non-traditional states like, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Jharkhand etc.

The eri silkworm is multivoltine in nature having five to six generations in a year. It is polyphagous in nature and feeds on various types of food plants *viz.* Castor, Kesseru, Borpat, Borkesseru, Tapioca, etc. It was reported that though Castor and Kesseru are the most preferred food plants for commercial eri silkworm rearing and eri silk production, Borpat (*Ailanthus* spp.) leaves can also be best utilized for rearing of the silkworm during scarcity of major host leaves [3-5]. However, information on interchange effect of food plants on degumming of cocoon and physical properties of the yarns is scanty, therefore the investigation was undertaken to find out the effect of interchange of host plant.

2. MATERIALS AND METHODS

The experiment on effect of food plants *i.e*. castor (*Ricinus communis*), kesseru (*Heteropanax fragrans*) and borpat (*Ailanthus grandis*) and their interchange (Table 1) on eri silk yarn was carried out in the Department of Sericulture, Faculty of Agriculture, Assam Agricultural University, Jorhat, during spring (March-April) season, 2014 by following the method suggested by Chowdhury [3]. In all the dietary regiments four replications consisting 0.50 gm of eggs (seed) in each replication were maintained.

Table 1. Combination of food plants in different treat efficacy

Experimental code	Combination of food plants
T_1	Castor (first to fifth instar)
T_2	Kesseru (first to fifth instar)
T_3	Borpat (first to fifth instar)
T_4	Castor (first to third instar) + Kesseru (fourth to fifth instar)
T_5	Castor (first to third instar) + Borpat (fourth to fifth instar)
T_6	Kesseru (first to third instar) + Castor (fourth to fifth instar)
T_7	Kesseru (first to third instar) + Borpat (fourth to fifth instar)
T_8	Borpat (first to third instar) + Castor (fourth to fifth instar)
T_9	Borpat (first to third instar) + Kesseru (fourth to fifth instar)

The degumming of eri cocoons was followed as suggested by Somashekar [6]. The degummed cocoons were squeezed and converted to cake. The cakes were dried and kept for spinning. After drying the weight of degummed cocoons (cakes) were taken and degumming loss was calculated by using the following formula and expressed in percentage.

$$\text{Degumming loss (\%)} = \frac{\text{Initial weight of the cocoons} - \text{ weight of the degummed cocoons}}{\text{Initial weight of the cocoons}} \times 100$$

Degumming period is the time required for removal of sericin, the gummy substance of silk, to make the cocoons soft and enable them for easy drafting. The time required for degumming of cocoons was recorded.

Spinning of the degummed cocoons were done in the Choudhury spinning machine to produce spun yarn. The degummed eri cakes after drying were fed to the machine to produce spun yarns. After spinning of the yarn, a hank of specific length of 109.7m (120 yards) was prepared in the Epprouvette with a circumference of 1.125m. Skeins were made in the Skeining machine and kept ready for testing. The yarns produced from degummed cocoons was weighed and expressed in percentage for each treatment combinations.

The size of the spun yarns produced from the cocoon of different dietary regiments were measured gravimetrically using the following formula by taking the length and weight of yarns and expressed as count "s".

$$\text{Count “s”} = \frac{5315}{\text{Denier}}$$

$$\text{Where, Denier} = \frac{\textit{Weight of the yarn in gram}}{\textit{Length of the yarn in metre}} \times 9000$$

The standard samples of eri spun yarns were tested for breaking load, tenacity and elongation at Central Silk Technological Research Institute, Bangalore and imperfection of the samples were measured at Northern India Textile Research Association, Ghaziabad, Uttar Pradesh.

Tenacity is expressed as breaking load in grams per denier of yarn. Elongation is the amount of the stretch when pulled to the breaking point and expressed as percentage. Tensile strength test of the spun yarn was performed according to I.S procedure (1670-1991) using KMI Tensile strength test with CRT (Constant Rate Traverse) principle. The imperfection expressed in percentage of spun yarn was tested as per ASTM procedure (B 1425-1987) using Uster Evenness Tester Model B, Type T. The test was performed at a speed of 25m/min and evaluation time was 1 minute.

The experiments were laid out in Completely Randomized Design (CRD) for various estimations of cocoon and yarn characters of eri silkworm where each dietary regiment was replicated four times. The experimental error of the various effects was determined by calculating their respective F-values [7].

3. RESULTS AND DISCUSSION

3.1 Degumming Loss

The data on degumming loss of the cocoons of eri silkworm reared on different sole and interchanged combinations of food plants are presented in Table 2. Results revealed that degumming loss of cocoons differed significantly in different food plants and their interchanged combinations. Among the sole food plants degumming loss was recorded significantly the highest (20.95%) in borpat (T_3) fed cocoons followed by kesseru (T_2) fed cocoons (19.25%), while castor (T_1)fed cocoons registered the lowest with 17.70% degumming loss. Among the food plant combinations borpat + kesseru (T_9) and kesseru + borpat (T_7) are recorded significantly higher degumming loss of 20.18% and 19.88%, respectively and found to be *at par* with each other. The combination of castor+borpat (T_5), kesseru + castor(T_6) and borpat+castor (T_8) registered degumming loss of 19.55%,18.98% and 19.10%, respectively and did not differ significantly in this respect. Though castor+kesseru (T_4) registered for the lowest degumming loss (18.75%), the combination was found to be *at par* with borpat+castor (T_8) in respect of degumming loss.

3.2 Degumming Period

Data presented in Table 2 showed that food plants and their interchange combinations had significant effect in degumming period of the eri cocoons. The degumming period was registered shortest (46.25min) for the cocoons of castor (T_1)

fed larvae and differed significantly from the rest sole and interchange combinations of food plants. Kesseru (T_2) and borpat (T_3) which registered degumming loss of 51.75min and 52.75min, respectively were *at par* in this respect. Interchange of food plants showed significant increase in degumming period of the cocoons. Among the interchange combinations kesseru + borpat (T_7) which registered for the longest degumming period (53.75min) was *at par* with borpat + kesseru (T_9) with 53.50min degumming period and did not differ significantly from that of sole borpat (T_3). The combination of castor + kesseru (T_4), castor + borpat (T_5) and borpat + castor (T_8) which registered 49.00min, 50.25min and 50.50min were *at par* and kesseru + castor (T_6) which registered 51.25min did not vary significantly from that of kesseru (T_2) and borpat (T_3) in this respect.

3.3 Yarn Parameters of eri Silkworm

Yarn yield: Significant difference ($p<0.05$) was observed in yarn yield from the cocoons of eri silkworm reared on the different sole and their interchanged combinations of the food plants(Table 2). Significantly the highest yarn yield (75.74%) was recorded from the cocoons obtained from castor (T_1) fed larvae followed by kesseru (T_2) and borpat (T_3) and fed larvae which recorded 74.18% and 72.50%, respectively. In all the interchanged combinations of the food plants the yarn yield were found to be significantly lower than the sole food plants. The food plant combination of castor + kesseru (T_4), castor + borpat (T_5) and kesseru + castor (T_6), borpat+castor (T_8) and borpat + kesseru (T_9) registered yarn yield of 72.28%, 72.05%, 72.16%, 72.01% and 72.02% respectively found to be *at par* with each other and did not differ significantly from that of sole borpat (T_3) in this respect. Though combination of kesseru + borpat (T_7) registered for the lowest yarn yield (71.80%), it did not vary significantly from all other combinations of food plants in respect of this parameter.

Yarn size: The data presented in Table 3 revealed that the food plants and their interchange combinations had significant effect ($p<0.05$) on size of eri spun yarn. Among the sole food plants the significantly the highest yarn size (14.06^S) was registered for castor (T_1) while it was lowest (13.95^S) for borpat (T_3). Yarn size also reported (10.26^S) in the autumn season and (9.09^S) in the early summer for borpat [8]. Kessseru (T_2) registered for the yarn size of 14.01^s did not vary significantly from both castor (T_1) and borpat (T_3). The food plant combination castor +kesseru (T_4), castor + borpat (T_5), kesseru + castor (T_6) and borpat + castor (T_8) registered yarn size of 13.93^s, 13.92^s, 13.89^s and 13.90^s, respectively and found to be *at par* with each other and did not very significantly from that of borpat (T_3). The combination of borpat+kesseru (T_9) registered for the lowest value of yarn size (13.07^s) which differed significantly from all other combinations.

Breaking load: Results presented in Table 3 revealed that among the sole food plants significantly the highest breaking load (0.63kg) was recorded in castor (T_1) followed by borpat (T_3) and kesseru (T_2) which recorded 0.61kg and 0.60kg, respectively. Though borpat+kesseru (T_9) registered for the lowest breaking load of 0.51kg, the combination was found to be *at par* with all interchange combinations of food plants *viz*., castor + borpat (T_5), borpat+castor (T_8) which recorded the breaking load of 0.58kg and 0.57kg, respectively.

Tenacity: The data on tenacity of eri silk yarn presented in Table 3 revealed that the food plants and their interchange combinations had no significant ($p<0.05$) effect on the tenacity of eri silk yarn. However, among the food plants the maximum tenacity (1.50 g/denier) was registered for castor (T_1). Kesseru (T_2) and borpat (T_3) behave equally in this respect with tenacity of 1.20g/denier. The tenacity of the eri silk yarn was revealed highest in the spring season (1.40g/denier) and lowest in the late summer (1.22g/denier) for barpat [8]. Interchange of food plants showed a decreasing trend on the tenacity of the yarns. Among the combinations the maximum tenacity (1.30g/denier) was recorded for castor + kesseru(T_4), kesseru + borpat(T_7) and borpat + castor (T_8). The combination of castor + borpat(T_5) and kesseru + castor (T_6) registered tenacity of 1.10 g/denier while borpat + kesseru(T_9) registered for the minimum tenacity (0.90g/denier) of the yarns.

Elongation: It is evident from the data presented in Table 3 that the food plants and their interchange combinations had no significant ($p<0.05$) effect on the elongation of eri silk yarn. However, among the food plants castor (T_1) recorded maximum elongation (19.30%) followed by borpat (T_3) and kesseru (T_2) with 18.90% and 17.70% elongation, respectively. Interchange of food plants showed a decreasing trend on the elongation of the yarns. Among the combinations

Table 2. Effect of food plantsand their interchange combinations on yarn yield and attributing parameters of eri silkworm cocoons

Host plant combination (Treatment)	Degumming loss (%)	Degumming period (min)	Yarn yield (%)
Castor (T_1)	17.70	46.25	75.74
Kesseru (T_2)	19.25	51.75	74.18
Barpat (T_3)	20.95	52.75	72.50
Castor+Kesseru (T_4)	18.75	49.00	72.28
Castor + Borpat (T_5)	19.55	50.25	72.05
Kesseru+Castor(T_6)	18.98	51.25	72.16
Kesseru+Borpat (T_7)	19.88	53.75	71.80
Borpat+Castor (T_8)	19.10	50.50	72.01
Borpat+Kesseru (T_9)	20.18	53.50	72.02
S.Ed(±)	0.30	0.75	0.27
CD at 5%	0.62	1.54	0.56

Data represent mean of 4 replications

Table 3. Yarn size, tensile strength and imperfection of the yarns produced from eri silkworm cocoons reared on different combinations of food plants

Host plant combinations (Treatment)	Yarn size (Count "S")	Breaking load (kg)	Tenacity (g/denier)	Elongation (%)	Imperfection (%)
Castor (T_1)	14.06	0.63	1.50	19.30	4.65
Kesseru (T_2)	14.01	0.60	1.20	17.70	4.45
Barpat (T_3)	13.95	0.61	1.20	18.90	4.68
Castor+Kesseru (T_4)	13.93	0.59	1.30	17.60	3.82
Castor + Borpat (T_5)	13.92	0.58	1.10	17.10	3.91
Kesseru+Castor(T_6)	13.89	0.59	1.10	16.30	3.78
Kesseru+Borpat (T_7)	13.84	0.59	1.30	17.40	3.85
Borpat+Castor (T_8)	13.90	0..57	1.30	16.50	3.98
Borpat+Kesseru (T_9)	13.07	0.51	0.90	16.90	3.80
SEd(±)	0.04	0.04	NS	NS	0.38
CD at 5%	0.08	0.08	NS	NS	0.78

Data represent mean of 4 replications
NS=Non significant

the maximum (17.60%) elongation was recorded for castor+kesseru (T_4) followed by kesseru+borpat(T_7), castor+borpat(T_5), borpat+kesseru(T_9) borpat+castor (T_8) which registered for 17.40%, 17.10%, 16.90% and 16.50% elongation, respectively while it was recorded minimum (16.30%) for the combination of kesseru+castor (T_6).

Imperfection: Results presented in Table 3 revealed that food plants and their interchange combinations have significant effect in the imperfection of the eri silk yarns. The sole food plants *viz*., castor (T_1), kesseru (T_2) and borpat (T_3) were *at par* with 4.65%, 4.45%, and 4.68% of imperfection and did not vary significantly from that of interchange combinations of castor + borpat(T_5) and borpat + castor (T_8) which registered 3.91% and 3.98% of imperfection. Though the combination of kesseru + castor (T_6) registered for the lowest value of imperfection (3.78%),it was found *at par* with castor + kesseru(T_4), kesseru + borpat(T_7) ,borpat + kesseru(T_9) which registered 3.82%, 3.85%, 3.80% imperfection, respectively and did not vary significantly from that of castor+borpat(T_5), borpat+castor (T_8) and kesseru (T_3) in this respect.

Yarn yield is the amount of silk that could be recovered from given amount of eri cocoons. Yarn yield usually proportional to cocoon shell weight and differs according to the shell ratio of the cocoons. The physical properties of eri spun yarn are technically important which contribute to the behaviour of the yarn in processing and to the quality of final product. The physical properties of eri silk yarn include yarn size (count

"S"), breaking load, tenacity, elongation percentage and imperfection. Tenacity is the breaking strength that the yarn can withstand till it breaks. Stress is strain, resulting in a greater length. Elongation is non-recoverable stretch. The combine property of strength and elongation of silk yarn is a measure of toughness of material which is related to weaving property [9]. Tensile properties are the important structural variants of silk yarn. The quality parameters of the degummed silk fibre are yarns can be measured with the variation of the tensile properties including strain, stress, tenacity etc. [10]. The present study revealed that food plants and their interchange combinations during rearing period had significant effect on yarn yield and degumming loss and degumming period. Among the sole food plants with maximum yarn yield, yarn size and minimum degumming loss and degumming period were registered in castor fed cocoons followed by kesseru fed cocoons. Though borpat fed cocoons registered lower values in respect of yarn yield and yarn size with higher degumming loss and longer degumming period, the food plants had no significant effect on physical properties *viz*., breaking load, tenacity, elongation percentage and imperfection. Maximum yarn yield was also found in castor than kesseru plant [11]. It was also revealed that with significantly lower degumming loss and shorter degumming period though yarn size was highest on castor fed cocoons, the physical characters of the yarn produced from borpat and barkesseru fed cocoons were significantly better than castor fed cocoons with no significant difference in respect of size of the yarns [12].

The interchange of food plants during rearing period had decreasing trend in respect of yarn yield and size of yarns than sole food plants, however, there was no significant difference among the interchange combinations of food plants in respect of yarn yield and physical properties of the yarns *viz.*, tenacity, elongation and imperfection. The combinations of castor with kesseru (castor + kesseru), castor with borpat (castor + borpat), kesseru with castor (kesseru + castor) and borpat with castor (borpat+castor) behave equally in terms of yarn size while the combination of borpat with kesseru (borpat+kesseru) was registered significantly the lowest value of yarn size. The sericin plays an important role in tensile characteristics of fibre [13]. It was reported that the strength and elongation of raw silk varied with species of silkworm, cocoon layers and rearing season [14]. Since eri cocoon is non-reelable, therefore the tensile strength of the spun yarn cannot be measured according to layers of cocoon as it obtained in tasar cocoons [15].It was also found that the elongation percentage decreased with increase in size of cocoon filament and increase with removal of sericin from the cocoons [16].

4. CONCLUSION

Thus, from the present investigation it is imperative to conclude that though castor is considered best, kesseru and borpat are equally suitable for rearing and cocoon production of eri silkworm considering the yarn yield as well as physical characters of the yarns produced from the cocoons. Interchange of castor, kesseru and borpat during rearing period though decreases the yarn yield of eri silkworm, there was no significant effect on yarn yield and physical properties of the yarns *viz.*, tenacity, elongation and imperfection among the combinations. Hence, the food plants could be effectively utilized for rearing of eri silkworm either in sole or in combinations for successful cocoon crop harvest and quality silk yarn production.

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 manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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