A Comparative Study about Tensile Properties of *A. assamensis* Helfer (Muga Silkworm) Reared on Different Host Plants

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Abstract: ***The protein-based biomaterial of silkworm silk is made by the silk glands of some arthropods like silkworms, spiders, scorpions, mites, and fleas, etc. Growth and silk productivity of silkworm is influenced by the nutritional content which affects the fortification of food plant leaves with supplementary nutrients. It is needed to fulfill the nutritional requirement to promote better growth with elevated economic characters. The tensile properties of various silk are of important structural variants of silk fiber and the quality parameters of the degummed fiber can be measured with the variation of the tensile properties including strain, tenacity, young's modulus, toughness, etc. The Muga silk fiber possesses the highest tenacity of the silk threads among the other silk fibers. The fibers of the six different and the wild counterpart of Muga silkworm were tested for breaking tenacity, percentage elongation at break, Young's modulus, and toughness in a Universal Testing Machine (UTM) (model: 3343), from Instron Corporation, UK interfaced with a PC. From the result counterpart, the maximum tenacity was reported in kotia and minimum in aherua reared on P. bombycina and L. monopetala whereas in L. solicifolia it was found to be maximum in kotia than jarua. In strain also have the same result reveals the better nutrient value present in the reared host plant in the concerned period. Young's modulus and toughness of the silk thread were found to be different in result then tenacity and strain that maximum result recorded in bhodia and minimum in chotua reared on both the host plant P. bombycina and L. monopetala whereas in L. solicifolia was recorded to be maximum kotia than jarua. From the above result reveals that there is nutrient relationship between host plant and silk thread quality depend on the seasonal variety resulting selection of the host plants according to the rearing season for better production of the quality silk fiber.***

Keywords: *A. assamensis, P. bombycina, L. monopetala, L. solicifolia*, tenacity, strain, young modulous, toughness

1. Introduction

Silk cocoon is the lustre of silk is a protein-based fiber forming biomaterial made by silk glands present in the silkworm. Silk is the fibrous protein polymers that are spun into fibers by some arthropods such as silkworms, spiders, scorpions, mites, and fleas [1, 2] (Altman GH *et al*., 2003; Craig CL, 1997). Silk is important for its high strength, durability, luster, drapability, and other unique features compared to common cellulose and synthetic fibers in current use [3] (Reddy, 2010). Silks are differing in their composition, structure, and properties depending on various specific sources and functions 1, 4, 5 (Altman GH *et al*., 2003; Craig CL *et al*., 1999; Vollrath F, 2000). The main aim of Muga rearing is to produce high amount of silk yield. Comparison between the difference and relations among the cocoon characters may be taken into consideration for comprehensive selection [6] (Talukdar K, 2017). Moreover, it is of great help in predicting the rearing performance in different traits of cocoon characters [7] (Yadav and Goswami, 1999). Growth and silk productivity in silkworm is influenced by nutrition which suggested that the effect of fortification of food plant leaves with supplementary nutrient, needed to fulfill the nutritional requirement to promote better growth with elevated economic characters 8, 9, 10, 11, 12, 13 (Ito, 1967; Horie, 1978; Thangavelue, 1986; Babu, 1994; Nagesh *et al*., 1996; Dash, 1996). Silk is a proteinaceous fiber synthesized with complete metabolism of their host plant leaf protein by the silkworm[14] (Lokesh & Narayana., 2011). It is a continuous protein fiber (a fibrous biopolymer) produced by the silkworm so as to form the cocoon for their shelter and this cocoon has been exploited as a textile fiber. Over the muga silk thread, fibroin protein content contributes 70-80% while sericin protein contributes 20-30%. Moreover, the cocoon also has secondary ingredients such as waxy matter (0.4-0.8%), carbohydrates (1.2-1.6%), pigments (0.2%), and inorganic matter (0.7%) and the percentage of these ingredients varies in respect of silkworm strain, rearing seasons and ecological conditions (like temperature, humidity, etc.) at different geographical locations [15] (Thangavelu K and Chakrabarty A. K., 1985).

The tensile properties are of important structural variants of silk fiber and the quality parameters of the degummed fiber can be measured with the variation of the tensile properties including strain, tenacity, Young's modulus, toughness, etc.1[6] (Iizuka, E.1998). Strength and elongation tests are used widely for assessing fiber's degradation in textile substances. Sporadic studies have been conducted on physical properties like tensile strength, etc. on Muga silk fibers for academic interests. The "strain" of a fiber is the ratio of elongation of the fiber to the initial length whereas "tenacity" is the mass strength at break of silk thread [17] (Nath, *et al*., 2013). A high modulus produces inextensibility whereas a low modulus produces great extensibility of the fiber [18] (Booth, 1996). Regarding Antherean silk, the young's modulus, tenacity and density, etc. are lower and the elongation is higher as the mean thread size increase. It states that the thinner Antherean silk has a more developed fiber structure[16] (Iizuka, 1998). Out of the various silk threads, muga fibers possess maximum tenacity among all-natural fibers [19, 20] (Baruah, 1991; Talukdar, 2003). Within a cocoon, the tenacity of the fiber increases substantially and also the inner layers have fibers with high tenacity than fibers from the outer layer [21] (Sen, *et al*., 2004). The higher tenacity of the muga silk imparts a wide range of its use in various purposes [22] (Freddi, *et al*., 1984). In comparison to different colour morphs of muga silk like green, blue, orange, and wild counterpart, the green colour morphs of muga silk has the highest tensile strength [17] (Nath, *et al*., 2013). It was also reported by[19.20] (Baruah, 1991 and Talukdar, 2003) that among all-natural fibers, the muga silk fiber possesses the highest tenacity of the silk threads.

2. Materials and Methods

The rearing of *muga* silkworm was conducted in six different broods according to different season like-Bhadia (late summer), Kotia (autumn), Jarua (winter), Chotua (early spring), Jethua (spring), Aherua (summer) on two primary host plants, Som and Soalu in comparison with secondary host plant Dighlati in two season Kotia (autumn), Jarua (winter) at Govt. Basic Muga Seed Farm, Khanapara, Guwahati followed by[23] (Bharali, 1970b) at (22), 26º 12´ 16´´N latitude, and 91º 81´ 48´´E longitude and 99 metre MSL. The muga silk fibers were acclimatized in standard conditions of humidity (65%) and temperature (250C) for 24 hours. The fibers of the six different and the wild counterpart were tested for breaking tenacity, percentage elongation at break, Young's modulus and toughness in an Universal Testing Machine (UTM) (model: 3343), from Instron Corporation, UK interfaced with a PC. All the samples were mounted on the cross heads with a pre-tension of 0.02 gf/den. Gauge length of 5 cm and cross–head speeds of 20mm/min were chosen for conducting the tests.2.3 Statistical analysis all the data have been collected and analyzed statistically. The standard deviation (SD) of seven replications has been used. Two-way Analysis of Variance (ANOVA) of the data has been done. The critical difference ($p<0.5\%$) is calculated out to know the relation among themselves. The results were revealed by using Standard error ± Standard (X ± SEM) error mean statistically through MS Office Excel 2010 and SPSS 17.0.

3. Results

The results on the tenacity of muga silk filament reared on three different host plants in six different broods were presented in the Figure 1 (A) ANOVA showed a significant difference in the plant, (F_1=5.377, P=0.023), season (F_5=04.09, P=0.003); plant and season (F_6=5.818, P<0.001). The strain of the silk thread Figure 2 (B) also showed a significant difference in the plant (F_1=4.061, P=0.048), plant and season (F_6=3.06, P=0.015) but not in season (F_5=1.975, P=0.093). Regarding young modulus, the results of muga silk thread in six different broods Figure 3 (C) showed significant variation in the plant (F_1=14.811, P<0.001), season (F_5=3.353, P<0.001), and plant and season (F_5=667.739, P=0.009). In respect of toughness of the mugasilk thread which varies significantly in sources like plants Figure 4 (D) (F_2=21.944, P<0.001), seasons (F_5=8.284, P<0.001), and plant and season (F_5=7.895, P<0.001).

The tenacity (Table-1.1 (A)) on silk filament of *A. assamensis* reared on *P. bombycina* with six different broods was recorded to be maximum in kotia (3.490^a±0.155dn) whereas minimum in aherua (2.013^a±0.134dn) (p<0.01) than rest of the other season whereas on *L. monopetala* with maximum in kotia (2.951^c±0.150dn) and minimum in aherua (1.564^a±0.237dn) (P<0.01). In *L. salicifolia* was found to be 2.85±0.4dn and 2.68±0.22dn in kotia and jarua season with maximum in kotia than jarua without any significant difference in six diferrent seasons.

The **s**train (Table-2.1 (B)) of the silk thread of muga silk for six diferrent broods reared on *P. bombycina* with maximum in Kotia (32.269^c±3.712%) and minimum in Aherua (15.972^a±2.878%) (p<0.05) in comparison to *L. monopetala* was to be maximum in Kotia (24.990^a±2.326%) and minimum in Aherua (11.982^a±3.295%) (p<0.05) whereas in *L. salicifolia* was found to be 7.00±2.65% and 5.17±1.95% during the season of Kotia and Jarua with maximum in Kotia than Jarua.

Regarding young modulus (Table-3.1 (C)) it was recorded with a maximum in Bhodia (84.977±3.940dn) and minimum in Chotua (49.648±4.766dn) (P<0.001) and in *L. monopetala* was recorded with a maximum in Bhodia (52.589±5.270 dn) and minimum in chotua (44.936±2.383dn) (P>0.05) rather in *L. salicifolia* was found to be 72.85±6.35dn and 66.54±3.57dn in Kotia and Jarua season with maximum (P>0.05) in Kotia than Jarua.

The toughness (Table-4.1 (D)) of the silk thread of *A. assamensis* for six different broods (Figure 4.3.4) was recorded maximum in Bhodia (1.171±0.142dn) and minimum in Chotua (0.286±0.047dn) (P<0.0001) reared on *P. bombycina* than in *L. monopetala* was recorded as maximum in Bhodia (0.489±0.102dn) and minimum in chotua (0.262±0.044dn) (P>0.05). It was found to be maximum in Kotia (0.59±0.08dn) than Jarua (0.26±0.05dn) reared on *L. salicifolia*.

4. Discussion

The Muga silk thread which is a protein in nature mainly depends on the nutrient facility of the larval stages of the muga silkworm. The nutritional quality of the host plant leaves of silkworm and their balanced proportion plays a vital role in the proper growth and development of silkworm larvae and also the cocoon characteristics of silkworm. In tenacity on the muga silk filament there is no significant difference except Bhodia than rest of the other season (P>0.001) in between *P. bombycina* and *L. monopetala* and in between *L. monopetala* and *L. salicifolia* without significant different in kotia and jarua (P>0.05).1[9, 20] The muga silk fiber possesses the maximum tenacity among all other natural fibers. The present result reveals the nutrient impact by the reared host plants according to different host plants.2[4, 25] Das, A. K., *et al*., 1992 and Yadav G. S., 2010 also reported that the leaf nutrition of silkworm on their host plant can enhance the effective rate of rearing (ERR), health and growth of the larvae and the better crop yields as the nutritious quality has direct correlation with cocoon and shell weights, silk ratio and filament of the silk thread. The **s**train of the silk thread of different seasons was recorded maximum in kotia and minimum in aherua reared on *P. bombycina*, whereas in *L. monopetala* was recorded to be maximum in kotia and minimum in aherua (P>0.05). And *L. salicifolia* was found to be maximum in kotia than jarua (P<0.01). There is no significant difference in various season except kotia (P<0.001) in between *P. bombycina* and *L. monopetala* whereas insignificant diferrence in Kotia (P>0.05) than rest of the season in between *L. monopetala* and *L. salicifolia*. In case of young modulous silkworm reared on *P. bombycina,* was recorded maximum in kotia and minimum in chotua (P<0.001); whereas on *L. monopetala* recorded maximum with kotia and minimum in chotua (P>0.05) followed by reared on *L. salicifolia* recorded with maximum in kotia than jarua (P>0.05). There is significant difference in bhodia and kotia (P<0.001) in between *P. bombycina* and *L. monopetala* whereas in between *L. monopetala* and *L. salicifolia* there is no significant difference in kotia than jarua (P>0.05). The toughness of the silk thread of muga silkworm reared on *P. bombycina* with maximum in kotia and minimum in chotua (P<0.0001); whereas on *L. monopetala* recorded to be maximum in kotia and minimum in chotua (P>0.05). On *L. salicifolia* recorded to be maximum in kotia than jarua (P<0.05). There is a significant difference in between *P. bombycina* and *L. monopetala* except jarua (P<0.05) and without significant difference (P>0.05) in between *L. monopetala* and *L. salicifolia*. From the result view we have to summarise one thing that itself *P. bombycina* and *L. monopetala* are the major host plant of *A. assamensis* but the rearing performance of the silk depend on the environmental condition. The secondary host plants are also give a better result in both the production and quality of the silk thread which is the main interest of the sericulture. The silk is mainly protein in nature which is directly correlate with the nutrient quality like moisture, tenderness, etc. of the host plant leaves which impact on the feeding habit of the silkworm and it directly effect on the production of the quality silk thread.

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Disclosure

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Supplementary Material

Supplementary Material for this article is available online.

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Figure Legends

Fig 1 (A)

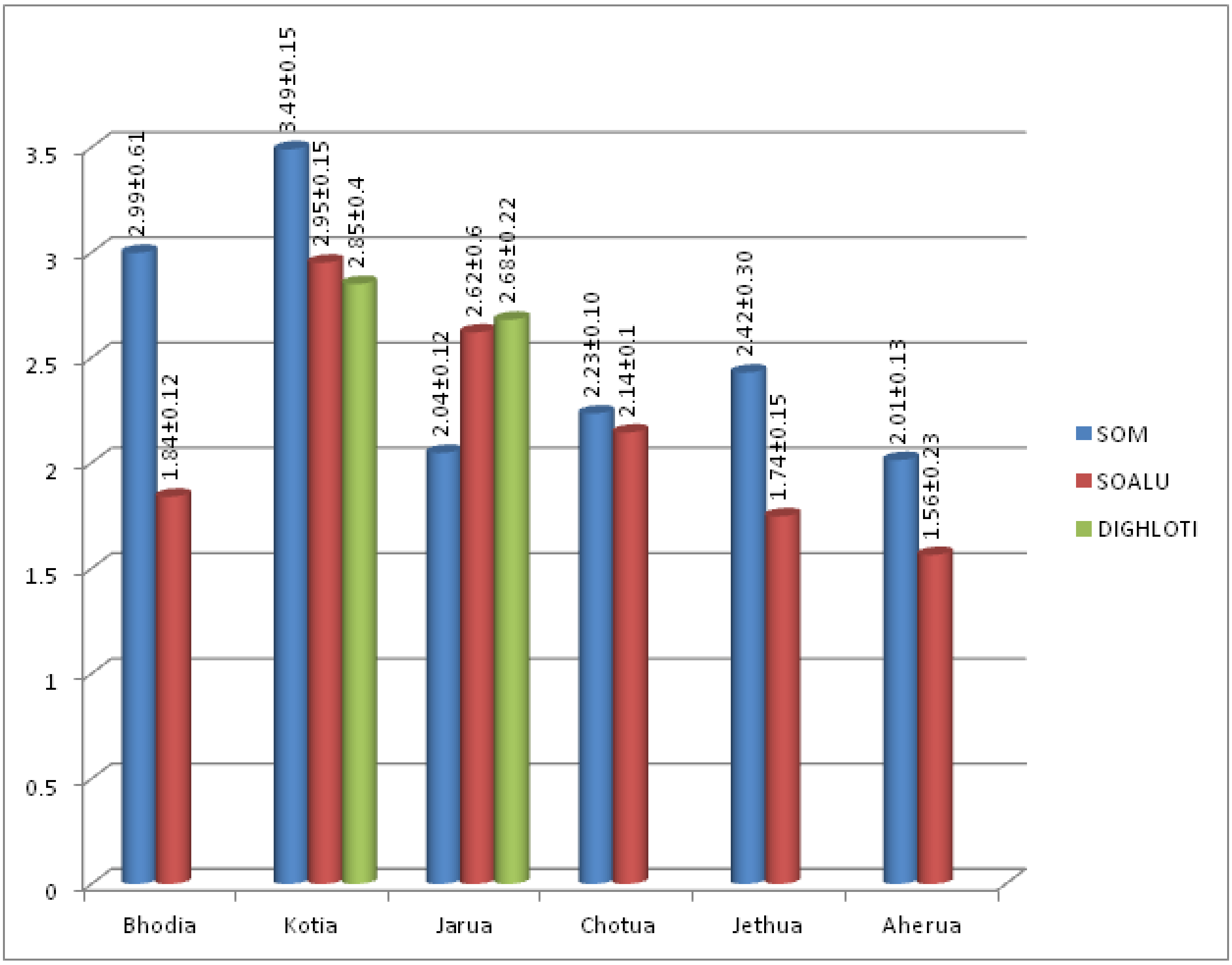

Figure 1 (A): Histogram showing the tenacity reared on two major host plants *P. bombycina* and *L. monopetala* reared for six different season and one secondary host plant *L. salicifolia* for kotia and jarua season.

Fig 2 (B)

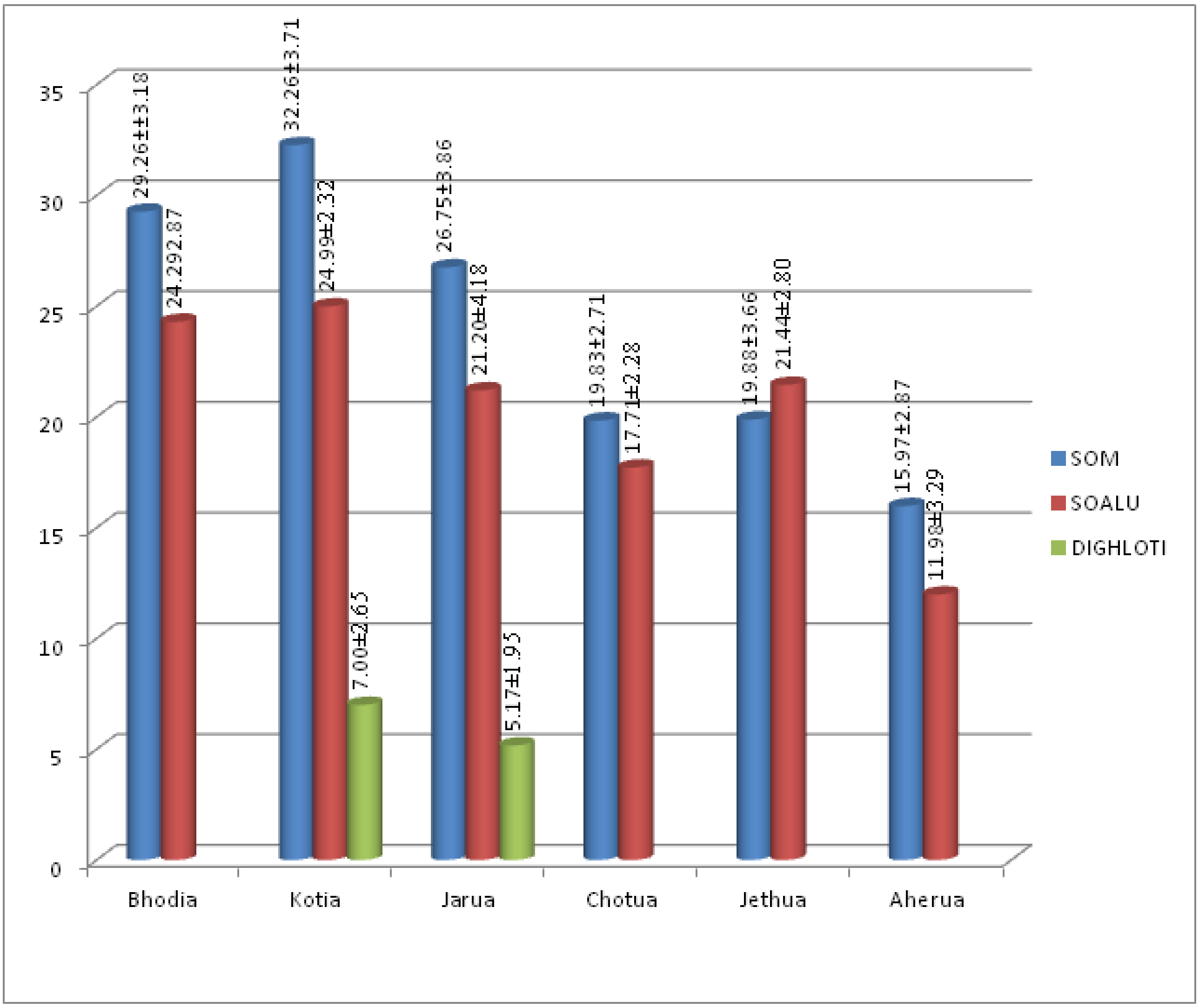

Figure 2 (B): Histogram showing the strain reared on two major host plants *P. bombycina* and *L. monopetala* reared for six different season and one secondary host plant *L. salicifolia* for kotia and jarua season.

Fig 3 (C)

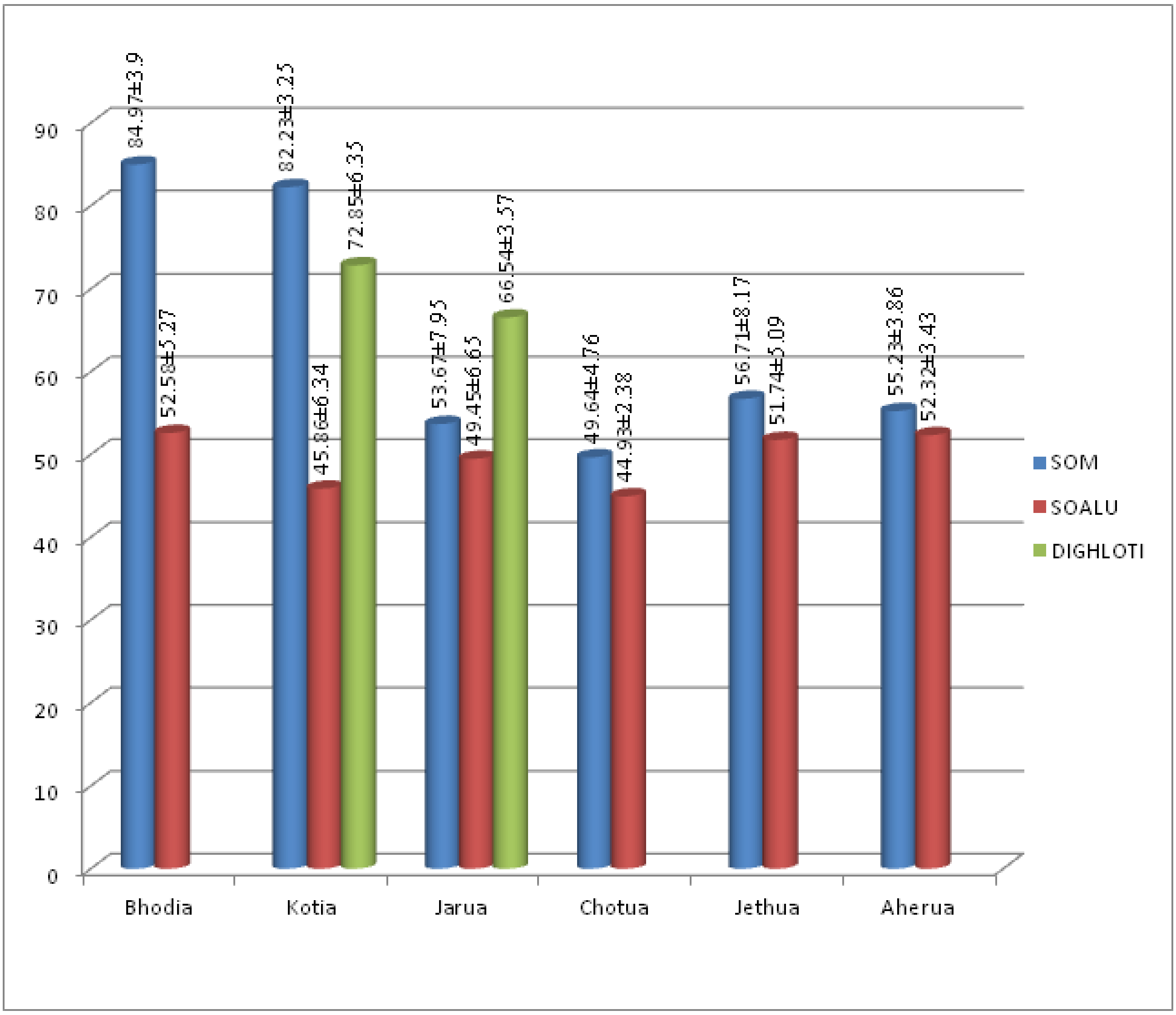

Figure 3 (C): Histogram showing young modulous reared on two major host plants *P. bombycina* and *L. monopetala* reared for six different season and one secondary host plant *L. salicifolia* for kotia and jarua season.

Fig 4 (D)

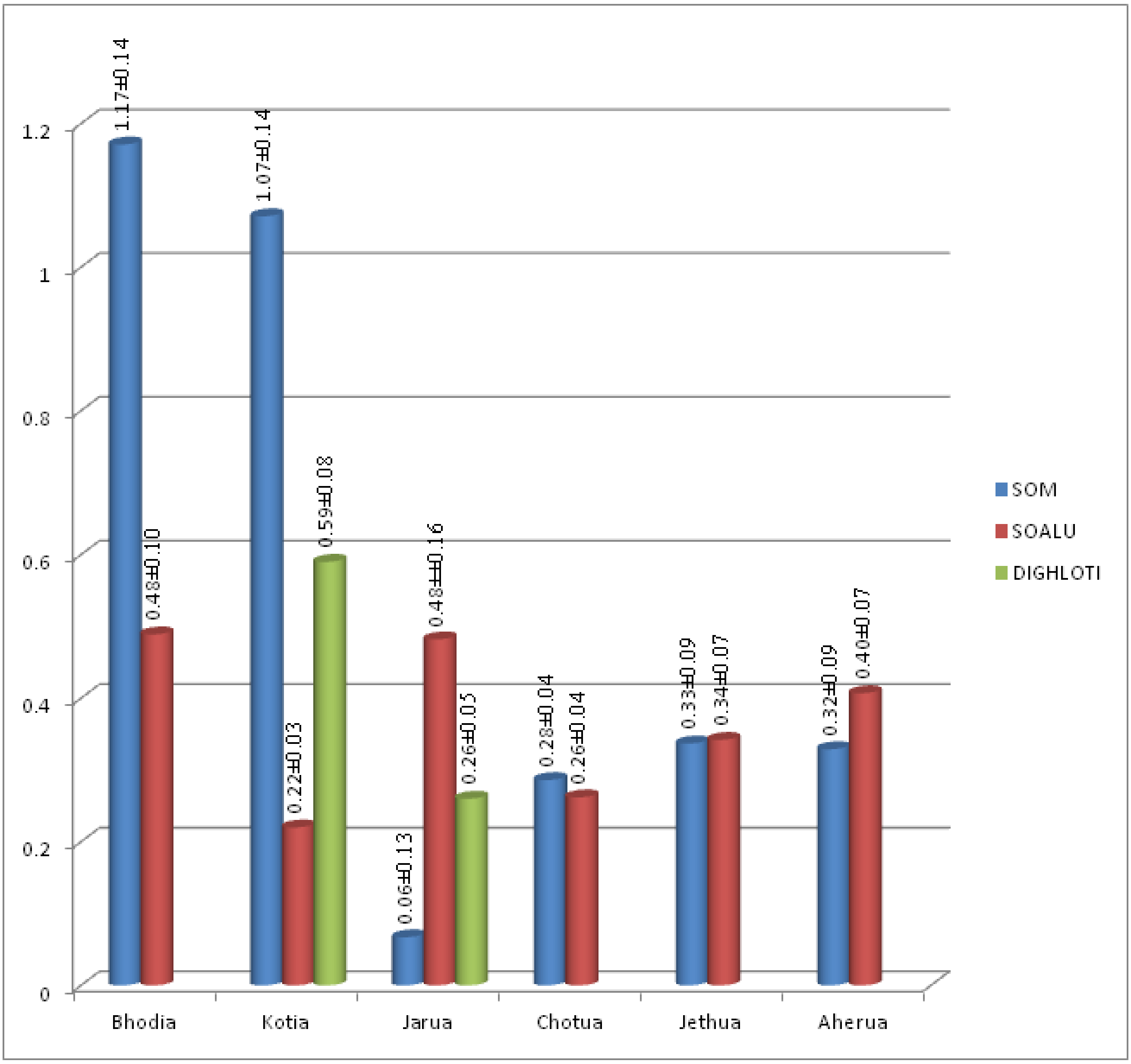

Figure 4 (D): Histogram showing toughness reared on two major host plants *P. bombycina* and *L. monopetala* reared for six different season and one secondary host plant *L. salicifolia* for kotia and jarua season.

Table Legends:

Table 1.1 (A)

SEASON	*SOM*	*SOALU*	*DIGHLOTI*
Bhodia	$2.998^{b}\pm0.610$dn	$1.841^{ab}\pm0.125$dn	
Kotia	$3.490^{a}\pm0.155$dn	$2.951^{c}\pm0.150$dn	2.85±0.4dn
Jarua	$2.047^{b}\pm0.122$dn	$2.620^{bc}\pm0.600$dn	2.68±0.22dn
Chotua	$2.234^{a}\pm0.107$dn	$2.144^{abc}\pm0.107$dn	
Jethua	$2.429^{a}\pm0.303$dn	$1.748^{ab}\pm0.154$dn	
Aherua	$2.013^{a}\pm0.134$dn	$1.564^{a}\pm0.237$dn	

Table 1.1 (A): Tables represents the tenacity of the muga silk thread reared on two major host plants *P. bombycina* and *L. monopetala* in comparison with one secondary host plant *L. salicifolia* for six different seasons.

Table 2.1 (B)

SEASON	*SOM*	*SOALU*	*DIGHLOTI*
Bhodia	$29.267^{bc}\pm3.188$%	$24.296^{a}\pm2.876$%	
Kotia	$32.269^{c}\pm3.712$%	$24.990^{a}\pm2.326$%	7.00±2.65%
Jarua	$26.753^{bc}\pm3.868$%	$21.201^{a}\pm4.182$%	5.17±1.95%
Chotua	$19.838^{ab}\pm2.712$%	$17.715^{a}\pm2.281$%	
Jethua	$19.887^{ab}\pm3.663$%	$21.447a^{a}\pm2.804$%	
Aherua	$15.972^{a}\pm2.878$%	$11.982^{a}\pm3.295$%	

Table 2.1 (B): Tables represents the strain of the muga silk thread reared on two major host plants *P. bombycina* and *L. monopetala* in comparison with one secondary host plant *L. salicifolia* for six different seasons.

Table 3.1 (C)

SEASON	***SOM***	***SOALU***	***DIGHLOTI***
Bhodia	84.977±3.940dn	52.589±5.270 dn	
Kotia	82.230±3.250dn	45.862±6.348dn	72.85±6.35dn
Jarua	53.671±7.954dn	49.459±6.650dn	66.54±3.57dn
Chotua	49.648±4.766dn,	44.936±2.383dn	
Jethua	56.712±8.176dn	51.747±5.092dn	
Aherua	55.235±3.865dn	52.323±3.435dn	

Table 3.1 (C): Tables represents the young modulous of the muga silk thread reared on two major host plants *P. bombycina* and *L. monopetala* in comparison with one secondary host plant *L. salicifolia* for six different seasons.

Table 4.1 (D)

SEASON	**SOM**	**SOALU**	**DIGHLOTI**
Bhodia	1.171±0.142dn	0.489±0.102dn	
Kotia	1.071±0.141dn	0.220±0.038dn	0.59±0.08dn
Jarua	0.067±0.136dn	0.482±0.161dn	0.26±0.05dn
Chotua	0.286±0.047dn	0.262±0.044dn	
Jethua	0.337±0.097dn	0.342±0.072dn	
Aherua	0.329±0.096dn	0.407±0.074dn	

Table 4.1 (D): Tables represents the toughness of the muga silk thread reared on two major host plants *P. bombycina* and *L. monopetala* in comparison with one secondary host plant *L. salicifolia* for six different seasons.