

COCOON PRODUCTION OF THE SILKWORM, *Bombyx mori* L. (LEPIDOPTERA: BOMBYCIDAE), FED ON LEAVES OF MULBERRY HYBRIDS¹

GERBSON AZEVEDO DE MENDONÇA², LUIS CARLOS MARCHINI³, LUCIANO PACELLI MEDEIROS
MACEDO^{4*}

ABSTRACT - Brazil is the fourth cocoon producer in the world. In São Paulo State there are mulberry some hybrids whose productivity are higher than the commonly cultivated varieties. The objective of this study was to evaluate the effect of mulberry hybrids (*Morus* spp.) on the cocoon production of silkworm (*Bombyx mori* L.). The experiment was conducted at the Unidade Regional de Pesquisa de Gália do Instituto de Zootecnia, SP. The caterpillars were fed on leaves of the hybrids IZ-3/2, IZ-13/6, IZ-15/7, IZ-19/13, IZ-56/4, IZ-57/2, IZ-40, IZ-64, in a rearing hut at 25 °C ± 3 °C and 75% ± 5% relative humidity. 'Korin' was used as standard. The hybrids affected the duration of the larval period and the weight of the caterpillars, prepupae and the silk glands as well. There was a reduction in the duration of larval development when the caterpillars had been fed with hybrid IZ-56/4 and the 'Korin' variety. Hybrids IZ-57/2, IZ-56/4 and IZ-15/7 presented the highest cocoon production.

Keywords: Biology. Insecta. Sericulture. Silkworm.

PRODUÇÃO DE CASULOS DO BICHO-DA-SEDA [*Bombyx mori* L. (LEPIDOPTERA: BOMBYCIDAE)] ALIMENTADO COM FOLHAS DE HÍBRIDOS DE AMOREIRA

RESUMO - O Brasil é o quarto produtor mundial de casulos do bicho-da-seda, embora a produtividade ainda seja baixa. Em São Paulo existem alguns híbridos de amoreira (*Morus* spp.) cuja produtividade é maior do que aquela das variedades cultivadas comercialmente. O presente estudo teve como objetivo avaliar o efeito desses híbridos sobre a produção de casulos do bicho-da-seda (*Bombyx mori* L.). Os experimentos foram conduzidos na Unidade Regional de Pesquisa de Gália, do Instituto de Zootecnia, em Gália, SP. As lagartas foram alimentadas com os híbridos IZ-3/2, IZ-13/6, IZ-15/7, IZ-19/13, IZ-56/4, IZ-57/2, IZ-40, IZ-64 e a variedade 'Korin', em sirgaria com temperatura média de 25 ± 3 °C e 75 ± 5% de umidade relativa. Os híbridos afetaram a duração do estágio larval, o peso das lagartas, das pré-pupas e das glândulas sericígenas. Ocorreu redução na duração do desenvolvimento larval quando as lagartas foram alimentadas com o híbrido IZ-56/4 e com a variedade 'Korin'. Os híbridos IZ-57/2, IZ-56/4 e IZ-15/7 apresentaram as maiores produções de casulos.

Palavras-chave: Biologia. Insecta. Seda. Sericicultura.

* Autor para correspondência.

¹Recebido para publicação em 22/02/2010; aceito em 02/08/2010.

²Departamento de Agropecuária, UFRN, 559072-970, Natal - RN; gerbson@ct.ufrn.br

³Departamento de Entomologia, ESALQ/USP, 13418-910, Piracicaba - SP; lcmarchi@esalq.usp.br

⁴Laboratório de Biotecnologia, IFRN/Campus Ipangaçu, 59508-000, Ipangaçu - RN; luciano.macedo@ifrn.edu.br

INTRODUCTION

The silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae), was domesticated more than a thousand years ago. The studies on this had important advances in the last century, mainly on the fields of genetic and biotechnology. Through genetic improvement, new races have been developed, which produce more silk than those developed by the end of the nineteenth century. Although the currently bred races are much productive, the application of new technologies will promote increases in silk (GOLDSMITH et al., 2005).

Brazil is the fourth silkworm cocoon producer. However, despite its economic importance, the productive is still low. Brazilian sericulturists will be able to improve their productivity with the use of the mulberry hybrids developed at the Zootecnic Institute of São Paulo. The agronomic and reproductive characteristics of these hybrids have been studied by several researchers (FONSECA et al., 1985a,b; 1986; 1987a,b,c; 1993a,b; 2000; 2005; OKAMOTO et al., 1993; PORTO; OKAMOTO, 2000; PORTO et al., 1998; 2003). Their results indicate that the new hybrids are more productive than the common varieties still growing in the state (FONSECA et al., 1990; OKAMOTO; RODELLA, 2004).

Due the lack of information on the effect of these hybrids on silk production, the objective of this study was to evaluate the caterpillar development and the cocoon production of the silkworm fed with leaves of eight mulberry hybrids.

MATERIAL AND METHODS

The study was carried out at the Unidade Regional de Pesquisa de Gália do Instituto de Zootecnia – SP. The experiment was arranged in a completely randomized design with nine treatments and replicates. Mulberry ‘Korin’, was included as the check. The caterpillars were reared on leaves of mulberry hybrids IZ-3/2, IZ-13/6, IZ-15/7, IZ-19/13, IZ-56/4, IZ-57/2, IZ-40, IZ-64, and ‘Korin’ for 28 days. The plants were approximately eight years old and had been pruned sixty days before the beginning of the experiment.

Eggs of commercial hybrid race of *B. mori* were separated into nine groups of 0.5g in Petri dishes and incubated at 26 ± 1 °C $80 \pm 5\%$ relative humidity, and 0h photofase for 11 days. After this period, a 12 hours photofase was provided from four 40W fluorescent light bulbs. Once they hatched, 58 caterpillars were transferred to wooden boxes (30 x 20 x 2 cm) and incubated in an experimental hut at 27 ± 1 °C, $75 \pm 5\%$ relative humidity, and 12 hour photofase, until the end of 2nd instar. They were fed five times a day, at 7, 10, 13, 16 and 19 h. The food

consisted of tender leaves from the apical end of the plants. At the second molting, the caterpillars were transferred again to bigger wooden boxes (80 x 70 x 3 cm) and incubated in a hut at 25 ± 3 °C, and $75 \pm 5\%$ relative humidity. The rearing boxes were placed on a wooden platform 70 cm high, disinfected with formaldehyde 3% five days earlier. All molting were powdered hydrated; whitewash was used on the caterpillars to prevent virus diseases. The food of the third and fourth instars consisted of the two superior thirds of the mulberry branches; at the fifth instar, entire branches were provided. The identification of each instar, was made based on the immobility period of the caterpillars that occurs between molts.

After the emergence of the first prepupae, three caterpillars per replication were used to determine the weight at the maximum larval development and three prepupae were killed by cooling and dissected to obtain the silk gland weight. Six days after spinning, the silk production was weighed on a precision scale. Thirty cocoons of each replication were used to assess the cocoon, the pupae, and the silk shell weights. The silk content was determined by the ratio between the silk shell weight and the cocoon weight, in percentage, minus 24% of residues, as usually calculated in the commercial rearing.

The analysis of the data was performed using the F test and the mean separation ($P \leq 0.05$) were accomplished using Tukey’s multiple range.

RESULTS AND DISCUSSION

The duration of the first of silkworm instar did not differ among the treatments, although the insects fed on IZ-3/2, IZ-19/13, IZ-56/4 and ‘Korin’ presented a trend for a shorter period (Table 1), whereas the second instar was longer on IZ-40. At the third instar, there was not significant differences among the treatments. The hybrid IZ-56/4 and the variety ‘Korin’ provided shorter periods for the fourth instar. Significant differences among the treatments observed in the fifth instar, which influenced all larval periods. The shortest for this instar were observed when the caterpillars were fed the on ‘Korin’ and on IZ-56/4 and IZ-15/7. The hybrids that negatively affected the larval development probably have poor nutritional quality. The differences detected on the fifth instar may be attributed to the higher leaf consumption in this stage reaching at 85% of the consumption of the larval phase (PRAKASH; DELVI, 1987). According to Negreiros et al. (1994), the occurrence of a longer duration of the larval phase in eri-silkworm (*Philosamia ricini*) fed on castor bean genotypes suggests that some of these genotypes can be less adequate to this species.

Table 1. Duration of the instars of *Bombyx mori* fed on leaves of eight mulberry hybrids.

Treatment (Hybrids)	Instars (days) ¹				
	1 st	2 nd	3 rd	4 th	5 th
IZ-3/2	4.12 a	3.25 ab	4.12 a	5.50 b	7.37 b
IZ-13/6	4.25 a	3.00 a	4.21 a	5.50 b	7.37 b
IZ-15/7	4.25 a	3.00 a	4.25 a	5.50 b	7.27 ab
IZ-19/13	4.12 a	3.18 a	4.10 a	5.50 b	8.12 c
IZ-56/4	4.12 a	3.00 a	4.12 a	5.00 a	7.12 ab
IZ-57/2	4.25 a	3.00 a	4.25 a	5.50 b	8.12 c
IZ-40	4.25 a	3.50 b	4.25 a	5.12 ab	8.24 cd
IZ-64	4.25 a	3.00 a	4.25 a	5.50 b	8.62 d
'Korin'(check)	4.12 a	3.25 ab	4.12 a	5.00 a	6.88 a

¹Means within a column followed by a common letter are not different according to Tukey's multiple-range test ($P < 0.05$).

According to Machii and Katagiri (1991), the duration of the larval development of *B. mori* differs with the variety of mulberry on which the caterpillars are reared. In this study, 'Korin' and IZ-56/4 provided the shortest duration of the larval phases, whereas IZ-64 and IZ-40 resulted in longest ones (Table 2). Different caterpillar weights were observed by Sharma et al. (1986) with an Indian race of the silkworm fed on different mulberry varieties. According to these authors, the poor nutritional

quality of the food resulted in lower caterpillar weight, which was compensated by a length of the larval phase. In this study, the hybrids IZ-19/13, IZ-57/2, IZ-40 and IZ-64 resulted in a larval period longer than 25 days. However, they did not result in higher larval weight. According to Awmack and Leather (2002) the high cost of the digestibility in response to the low quality food leads to modifications in the development of the insect, such as longer larval phase and lower body weight.

Table 2. Biological parameters of *Bombyx mori* fed on leaves of eight mulberry hybrids.

Treatment (Hybrids)	Duration of larval phase (days) ¹	Caterpillar weight (g) ¹	Prepupa weight (g) ¹	Silk gland weight (g) ¹	Spinning (%) ¹
IZ-3/2	24.36 b	5.53 ab	4.76 ab	1.95 ab	84.08 ab
IZ-13/6	24.33 b	5.63 a	5.19 a	2.06 a	81.81 ab
IZ-15/7	24.27 ab	5.66 a	4.78 ab	1.90 abc	84.76 a
IZ-19/13	25.03 bc	5.41 ab	4.73 ab	1.75 bc	79.54 ab
IZ-56/4	23.36 a	5.52 ab	4.65 ab	1.78 bc	83.40 ab
IZ-57/2	25.22 bc	5.45 ab	4.77 ab	1.87 abc	83.17 ab
IZ-40	25.36 c	5.51 ab	4.45 b	1.72 bc	77.27 b
IZ-64	25.65 c	5.52 ab	4.33 b	1.68 c	79.76 ab
'Korin'(check)	23.37 a	5.06 b	4.57 b	1.85 abc	82.04 ab

¹Means within a column followed by a common letter are not different according to Tukey's multiple-range test ($P < 0.05$).

The differences found among the caterpillar weights were similar to those observed in the prepupae weights. Tayade and Jawale (1984) observed prepupae weights between 3.62 and 4.5g according

to the mulberry variety the caterpillars had been fed (with *B. mori* races and different mulberry varieties). Saratchandra et al. (1992) registered 3.83 to 4.91g for the prepupae weight, values that approach those

observed in this work.

The silk glands weight was higher on caterpillars fed on the hybrid IZ-13/6, which was significant different from those fed on IZ-64. Hybrids that lead to lower weight prepupae also results in low silk gland weight. According to Takahashi et al. (1990), food quality affects the development of silkworm glands. Part of the weight gain reached by the insect is directed related to the growth of the silk glands (MIRANDA et al., 2002), as found in this study.

The interval observed for the amount of caterpillars that had formed cocoon of 77.27 to 84.76% was lower than that determined by Sharma et al (1986) which varied from 60 to 100% and similar to that (75.1 – 83.5%) observed by Saratchandra et al. (1992). Although the results did not produce high statistical differences, in commercial silkworm rearing, these values can cause serious effects on the

cocoon production, since hundreds of thousands of caterpillars are normally created. For studies on the silkworm it is more interesting to observe the spinning percentage than the larval viability, since only the caterpillars that weave the cocoon have commercial or biological value.

The hybrid IZ-64 provided the lowest cocoon weight (Table 3). There were no significant differences among the treatments that resulted on cocoons with more than 2.2 g. Similar results were found by Machii and Katagiri (1991), and who obtained Fonseca et al. (1990).

The cocoon weight, as well as the pupae weight, depends on the mulberry genotype on which the caterpillar fed during the larval stage. This is important to quantify the cocoon production and in the determination of the silk content.

Table 3. Weight of cocoon, pupae, silk shell, and silk content of *Bombyx mori* fed on leaves of eight mulberry hybrids

Treatment (Hybrids)	Cocoon weight (g) ¹	Pupae weight (g) ¹	Silk shell weight (g) ¹	Silk content (%) ¹
IZ-3/2	2.22 ab	1.75 ab	0.502 ab	17.34 ab
IZ-13/6	2.28 a	1.76 a	0.518 a	17.44 ab
IZ-15/7	2.28 a	1.76 a	0.510 ab	17.18 ab
IZ-19/13	2.29 a	1.78 a	0.513 ab	17.15 ab
IZ-56/4	2.30 a	1.78 a	0.517 a	17.26 ab
IZ-57/2	2.26 a	1.74 ab	0.526 a	17.71 a
IZ-40	2.12 bc	1.64 b	0.478 bc	17.26 ab
IZ-64	2.00 c	1.53 c	0.464 c	17.77 a
'Korin' (check)	2.25 ab	1.75 a	0.492 abc	16.81 b

¹Means within a column followed by a common letter are not different according to Tukey's multiple-range test (P<0.05).

In commercial production of silk, the silk shell weight directly affects the silk content of the cocoon, through which the value of the production is determined. The higher the silk shell weight and the lower the pupae weight, greater will be the silk content. In this study, the hybrids IZ-64 and IZ-40 resulted in lowest biological parameter values, such as the duration of the larval stage and pupae weight.

CONCLUSIONS

The mulberry hybrid IZ-56/4 and the variety 'Korin' resulted in the shortest larval stage. The silk content was higher when the caterpillars were fed on the hybrids IZ-57/2 and IZ-64. Except for IZ-64, all hybrids resulted in similar cocoon weight, but was not significantly different from the check 'Korin'.

REFERENCES

- AWMACK, C. S.; LEATHER, S. R. Host plant quality and fecundity in herbivorous insects. **Annual Review of Entomology**, v. 47, p. 817–44, 2002.
- FONSECA, A. S.; FONSECA, T. C.; PAOLIERI, L. Natural hybrids of mulberry. **Boletim da Indústria Animal**, Nova Odessa, v. 42, n. 1, p. 71-77, 1985 a.
- FONSECA, A. S.; FONSECA, T. C.; PAOLIERI, L. Melhoramento da amoreira por meio de hibridação artificial. **Boletim da Indústria Animal**, Nova Odessa, v. 42, n. 2, p. 265-276, 1985 b.
- FONSECA, A. S.; FONSECA, T. C.; CHAMASS, E. A. Competição de híbridos naturais e artificiais de amoreira. **Boletim da Indústria Animal**, Nova O-

dessa, v. 43, n. 2, p. 367-73, 1986.

FONSECA, A. S.; FONSECA, T. C.; CHAMASS, E. A. Competição de híbridos artificiais de amoreira. II. **Boletim da Indústria Animal**, Nova Odessa, v. 44, n. 2, p. 315-322, 1987 a.

FONSECA, A. S.; FONSECA, T. C.; CHAMASS, E. A. Competição de híbridos naturais e artificiais de amoreira. III. **Boletim da Indústria Animal**, Nova Odessa, v. 44, n. 2, p. 323-328, 1987 b.

FONSECA, A. S. et al. Competição de variedades, híbridos naturais e artificiais de amoreira. IV. **Boletim da Indústria Animal**, Nova Odessa, v. 44, n. 2, p. 329-334, 1987 c.

FONSECA, T. C.; ALMEIDA, J. E.; FONSECA, A. S. Effect of mulberry selection in silkworm feeding. **Sericologia**, v. 30, n.4, p. 475-477, 1990.

FONSECA, T. C. et al. Valeur nutritive de quelques clones de mûrier (*Morus alba* L.). **Sericologia**, v. 33, n. 4, p. 623-630, 1993 a.

FONSECA, T. C.; ALMEIDA, J. E.; OKAMOTO, F. Le programme d'amélioration du mûrier dans l'Etat de São Paulo au Brésil. **Sericologia**, v. 33, n. 4, p. 623-630, 1993 b.

FONSECA, T. C.; CUCO, S. M.; MACHADO, S. Aspectos da morfologia floral da amoreira (*Morus alba* L.). **Boletim da Indústria Animal**, Nova Odessa, v. 57, n. 1, p. 33-38, 2000.

FONSECA, T. C. et al. Étude comparative de l'expression du sexe chez le mûrier, *Morus alba* L. - Développement floral. **Sericologia**, v. 45, n. 1, p. 17-28, 2005.

GOLDSMITH, M. R.; SHIMADA, T.; ABE, H. The genetics and genomics of the silkworm, *Bombyx mori*. **Annual Review of Entomology**, v. 50, p. 71-100, 2005.

MACHII, K.; KATAGIRI, K. Varietal differences in nutritive values of mulberry leaves for rearing silkworms. **Japan Agricultural Research Quarterly**, v. 25, p. 202-208, 1991.

MIRANDA, J. E.; BORTOLI, S. A.; TAKAHASHI, R. Effects of three juvenile hormone analogues applied on the silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae). **Neotropical Entomology**, v. 31, n. 1, p. 19-25, 2002.

NEGREIROS, J. et al. Efeito de genótipos de mamona sobre a biologia do bicho-da-seda *Philosamia ricini* (Drury, 1777) (Lepidoptera: Saturniidae). **Revista Caatinga**, Mossoró, v. 8, n. 1-2, p. 52-57,

1994.

OKAMOTO, F.; RODELLA, R. A. Produção de casulos do bicho-da-seda (*Bombyx mori* L.) e sua relação com características morfológicas e bromatológicas da folha de amoreira (*Morus* spp.). **Boletim da Indústria Animal**, Nova Odessa, v. 61, n. 2, p. 111-119, 2004.

OKAMOTO, F. et al. Avaliação do índice de pegamento em clones de amoreira (*Morus alba* L.). **Boletim da Indústria Animal**, Nova Odessa, v. 50, n. 1, p. 25-29, 1993.

PORTO, A. J.; OKAMOTO, F.; ALMEIDA, J. E. Effet de quatre clones de murier (*Morus* spp.) a trois stades de developpement sur lês caracteristiques du cocon du ver a soie (*Bombyx mori* L.). **Sericologia**, v. 38, n.2, p. 347-351, 1998.

PORTO, A. J.; OKAMOTO, F. Sistemas de utilização de dois cultivares de amoreira em duas idades de crescimento vegetativo, no desempenho do bicho-da-seda (*Bombyx mori* L.). **Boletim da Indústria Animal**, Nova Odessa, v. 57, n. 2, p. 171-178, 2000.

PORTO, A. J.; OKAMOTO, F.; OTSUKI, I. P. Estudo de cultivares de amoreira e de técnicas de manejo alimentar no desempenho do bicho-da-seda (*Bombyx mori* L.). **Boletim da Indústria Animal**, Nova Odessa, v. 60, n. 1, p. 71-82, 2003.

PRAKASH, R. N.; DELVI, M. R. Food utilization in different races of silkworm *Bombyx mori* (Lepidoptera: Bombycidae). **Sericologia**, v. 27, n.3, p. 391-397, 1987.

SARATCHANDRA, B. et al. An evaluation of elite mulberry varieties for yield and quality through bio-assay. **Sericologia**, v. 32, n.1, p. 127-34, 1992.

SHARMA, B.; BADAN, P.; TARA, J. S. Comparative consumption, utilization, % pupation and silk production in silkworms (*Bombyx mori* L.) fed on various varieties of mulberry existing in Jammu Division of Jammu & Kashmir State. **Sericologia**, v. 26, n. 4, p. 419-21, 1986.

TAYADE, D. S.; JAWALE, M. D. Studies on the comparative performance of silkworm races against different varieties of mulberry under Maratkwada conditions. **Sericologia**, v. 24, n. 3, p. 361-4, 1984.

TAKAHASHI, R.; KRONKA, S. N.; HIROSE, T. Desenvolvimento da glândula sericígena do bicho-da-seda (*Bombyx mori* L.) sob a influência de diferentes tipos de adubação na amoreira. **Boletim da Indústria Animal**, Nova Odessa, v. 47, n. 2, p. 121-125, 1990.