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## Effect of food and temperature on the development and silk production of *Bombyx mori* LINNAEUS

(Lepidoptera: Bombycidae)

### I. Introduction

The quality of food and the rearing temperature are of utmost importance for obtaining a good and healthy cocoon crop of silkworms. Mulberry leaves form the most suitable food for mass rearing of silkworm, *Bombyx mori* LINNAEUS. Work on the nutritive value of leaves from bush and male or female mulberry trees has been conducted (DE, 1917; CORRADINI, 1937), but not on leaves from seedling and grafted mulberry. The investigations reported here are on effect of latter types of food. The uni-voltine silkworms of the race Cevenne Jaune No. 45' were used.

### II. Materials and Methods

Overwintered disease free eggs were procured and hatched at 24 ( $\pm 0.5$ ) °C. The newly emerged larvae were fed on leaves from seedling and grafted varieties of *Morus alba* (LINNAEUS), the white mulberry, and *Morus nigra* (LINNAEUS), the black mulberry. Wooden trays (18"  $\times$  9"  $\times$  3") covered with muslin cloth, were used for rearing. These were kept in incubators which maintained constant temperatures of 20°, 25°, 30° (+ 0.5) °C with relative humidity varying from 60 to 70 per cent.

Larvae in the first and second stages were fed five times while those in the subsequent stages three times a day. The young larvae were offered chopped tender mulberry leaves, and the older larvae whole leaves. The rearing trays were cleaned occasionally with one per cent formalin solution.

Mature larvae just before pupation were kept individually in plastic petri dishes of 3" dia. with a circular filter paper at the bottom and a piece of muslin cloth on top, held fast with a rubber band. For each treatment the mature larvae were grouped at random into two, one for determining the weights of green cocoons, dry silk shells, live and dry pupae and the other for recording the duration of pupal period and adult life. The weighing of green cocoons, pupae and shells was done on the 8th day of spinning. The commencement of spinning was considered as the end of larval and the beginning of pupal stage, which means that the prepupal stage was always added to the pupal period. For determining the dry weights, the samples were kept overnight in an electric oven at 105 °C. The dry pupae and shells during transition from oven to balance were kept in desiccator containing anhydrous calcium chloride.

The least significant differences for comparison of results were calculated at the 5 per cent level. Means were based on 10 observations.

### III. Results and Discussion

#### 1. Speed of Development

In the experiments with silkworm a number of factors were combined, namely, food, temperature, and the sexes. The biological characteristics observed are presented in Tables 1 to 10.

Table 1

Mean live weight of mature larva (*MG*) at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperature		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	3887	4566	4044	4737	3811	4415	4226	4390	4113	3914	4572	4243
<i>M. nigra</i> seed.	3702	4391	4111	4846	3459	4238	4046	4475	3848	3757	4491	4124
<i>M. alba</i> graft.	2965	3232	3429	3873	3071	3390	3098	3651	3230	3155	3498	3326
<i>M. nigra</i> graft.	3040	3417	3751	4096	3086	3307	3228	3923	3196	3292	3306	3449
S.E. ±			(306.3) <sup>a</sup>				(216.5) <sup>b</sup>			(176.8) <sup>c</sup>		(125.0) <sup>d</sup>
Mean	3398	3901	3833	4388	3356	3837	3650	4110	3597	3529	4042	3785
S.E. ±			(153.1) <sup>e</sup>				(108.2) <sup>f</sup>			(88.4) <sup>g</sup>		

L.S.D. at 5 percent: (a) 603.2

(d) 246.2

(f) 213.1

(g) 174.1

Analysis of variance: temperature  $P < 0.001$ ; food  $P < 0.001$ ; sex  $P < 0.001$ ; interaction of sex  $\times$  food  $\times$  temperature  $P < 0.05$

A gradual and significant decrease in the larval and pupal period was observed when the temperature was raised from 20 to 25 and then to 30 °C, the duration recorded being 35.9, 26.6, 23.5 days for larvae and 23.9, 16.9, 14.6 days for pupae, respectively (Tables 2 and 5).

Larvae developed more quickly on seedling varieties of mulberry than on the grafted. The caterpillars took longer to complete development on *M. alba* grafted (30.3 days) than on *M. nigra* grafted leaves (29.5 days). There was no

Table 2

Mean length of larval life (hatching to pupation) in days at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	34.3	34.1	26.2	25.6	22.2	23.5	34.2	25.9	22.8	27.5	27.7	27.6
<i>M. nigra</i> seed.	35.8	33.6	25.5	25.1	21.6	22.5	34.7	25.3	22.0	27.6	27.0	27.3
<i>M. alba</i> graft.	38.5	38.3	27.8	29.0	24.7	23.7	38.4	28.4	24.2	30.3	30.3	30.3
<i>M. nigra</i> graft.	36.4	36.2	26.3	27.7	24.6	25.8	36.3	27.0	25.2	29.1	29.9	29.5
S.E. ±			(0.50) <sup>a</sup>				0.35) <sup>b</sup>			(0.29) <sup>c</sup>		(0.20) <sup>d</sup>
Mean	36.2	35.5	26.4	26.8	23.2	23.8	35.9	26.6	23.5	28.6	28.7	28.6
S.E. ±			(0.25) <sup>e</sup>				0.18) <sup>f</sup>			(0.14) <sup>g</sup>		

L.S.D. at 5 percent: (a) 0.98

(b) 0.68

(c) 0.57

(d) 0.39

(e) 0.49

(f) 0.35

Analysis of variance: temperature  $P < 0.001$ , food  $P < 0.001$ ; interactions: food  $\times$  temperature; sex  $\times$  temperature and sex  $\times$  food  $\times$  temperature  $P < 0.001$ , sex  $\times$  food  $P < 0.05$

significant difference between the speed of development of larvae reared on leaves from either of the seedling varieties (27.6 & 27.3 days on *alba* and *nigra*, respectively) (Table 2). However, in case of the pupal period trend was quite the reverse. The duration was longer when caterpillars were fed on leaves from seedling than on grafted varieties of mulberry (Table 5).

Table 3

Mean weight of live pupa (*MG*) at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	1271	1722	1528	2070	1801	1714	1497	1799	1507	1387	1835	1601
<i>M. nigra</i> seed.	1350	1847	1538	1848	1205	1478	1598	1693	1341	1364	1724	1544
<i>M. alba</i> graft.	975	1184	1313	1548	1031	1357	1079	1430	1194	1106	1363	1235
<i>M. nigra</i> graft.	1178	1435	1289	1602	1168	1354	1307	1446	1261	1212	1463	1338
S.E. ±			(80.7) <sup>a</sup>				(56.5) <sup>b</sup>			(46.6) <sup>c</sup>		(32.9) <sup>d</sup>
Mean	1193	1547	1417	1767	1176	1476	1370	1592	1326	1262	1596	1429
S.E. ±			(40.3) <sup>e</sup>				(28.5) <sup>f</sup>			(23.1) <sup>g</sup>		

L.S.D. at 5 percent: (a) 159.0 (b) 112.4 (c) 91.8 (d) 64.9 (e) 56.2 (f) 46.0 (g) 46.0

Analysis of variance: temperature P < 0.001; food P < 0.001; sex P < 0.001; interactions: food × temperature P < 0.001; sex × food × temperature P < 0.001; sex × food P < 0.01

The slow speed of larval development on leaves from grafted varieties of mulberry was associated with decrease in larval and pupal weights, weight of silk and fecundity of the resulting female moths (Tables 1, 3, 7, 9a). A nutritional deficiency is perhaps indicated. On *M. alba* grafted leaves the slow speed of larval development was associated with high death rate which, however, was not observed when *M. nigra* grafted leaves were offered as food, although development in this case was also rather slow (Table 9b).

Table 4

Mean ratio of live weight to dry matter in pupa at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	4.89	4.87	4.59	4.50	4.37	4.56	4.88	4.54	4.46	4.61	4.64	4.62
<i>M. nigra</i> seed.	5.19	4.92	4.45	4.45	4.68	4.62	5.05	4.45	4.65	4.77	4.66	4.71
<i>M. alba</i> graft.	4.64	4.65	4.80	4.70	4.78	4.82	4.64	4.75	4.80	4.74	4.72	4.73
<i>M. nigra</i> graft.	5.19	5.04	4.72	4.84	4.75	4.85	5.11	4.78	4.80	4.88	4.91	4.89
S.E. ±			(0.20) <sup>a</sup>				(0.14) <sup>b</sup>			(0.12) <sup>c</sup>		(0.08) <sup>d</sup>
Mean	4.97	4.87	4.64	4.62	4.64	4.71	4.92	4.63	4.67	4.75	4.73	4.74
S.E. ±			(0.10) <sup>e</sup>				(0.07) <sup>f</sup>			(0.06) <sup>g</sup>		

L.S.D. at 5 percent: (a) 0.40 (b) 0.28 (c) 0.16 (d) 0.14

Analysis of variance: temperature P < 0.001, food P < 0.05; interactions: food × temperature P < 0.05; food × sex × temperature P < 0.01

Table 5

Mean length of pupal period (days) at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	24.9	23.9	17.5	16.8	15.7	15.0	24.4	17.1	15.3	19.3	18.5	18.9
<i>M. nigra</i> seed.	24.4	23.9	17.7	18.1	14.5	14.9	24.1	17.9	14.7	18.8	18.9	18.8
<i>M. alba</i> graft.	24.0	22.6	16.4	16.3	14.1	14.8	23.3	16.3	14.4	18.1	17.9	18.0
<i>M. nigra</i> graft.	24.1	23.7	16.6	16.5	13.3	15.1	23.9	16.5	14.2	18.0	18.4	18.2
S.E. ±			(0.5) <sup>a</sup>				(0.3) <sup>b</sup>			(0.3) <sup>c</sup>		(0.2) <sup>d</sup>
Mean	24.3	23.5	17.0	16.9	14.4	14.9	23.9	16.9	14.6	18.5	18.4	18.4
S.E. ±			(0.2) <sup>e</sup>				(0.1) <sup>f</sup>			(0.1) <sup>g</sup>		

L.S.D. at 5 percent: (a) 1.0

(c) 0.6

(d) 0.4

(e) 0.5

(f) 0.3

Analysis of variance: temperature  $P < 0.001$ ; food  $P < 0.001$ ; interactions: sex  $\times$  food  $\times$  temperature  $P < 0.001$ ; sex  $\times$  temperature  $P < 0.01$ , sex  $\times$  food  $P < 0.05$ 

## 2. Survival

The quality of food and temperature had a direct effect on the survival rate and general activity of the insect. The survival among caterpillars reared at 30 °C was considerably lower (51.0%) than at 20 °C (82.5%) or at 25 °C (80.5%). On *M. alba* grafted leaves survival was lower (56.7%) than on any other food. The low survival was associated with slow speed of development and reduced body weight. On *M. nigra* grafted leaves also larvae had longer larval life and reduced body weight although percentage survival was comparatively higher (80.7%) than on leaves from seedling varieties (74.0% both on *alba* and *nigra*) (Tables 1, 2, 9b).

The insects reared on poor quality food (leaves from grafted varieties of mulberry) were small in size. Many of them died prematurely and some showed deformities in wings and antennae. The wings were small and antennae reduced. When larvae were reared at high temperature the moths developed bent antennae.

Table 6

Mean weight of green cocoon (MG) at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	1529	2010	1880	2435	1547	2004	1769	2158	1776	1652	2150	1901
<i>M. nigra</i> seed.	1625	2150	1875	2208	1428	1723	1887	2041	1576	1643	2027	1835
<i>M. alba</i> graft.	1200	1413	1593	1795	1217	1577	1307	1694	1397	1337	1595	1466
<i>M. nigra</i> graft.	1475	1671	1573	1878	1392	1574	1573	1725	1483	1480	1707	1594
S.E. ±			(79.9) <sup>a</sup>				(56.5) <sup>b</sup>			(46.2) <sup>c</sup>		(32.6) <sup>d</sup>
Mean	1457	1811	1730	2079	1396	1720	1634	1904	1558	1528	1870	1699
S.E. ±			(39.9) <sup>e</sup>				(28.2) <sup>f</sup>			(23.0) <sup>g</sup>		

L.S.D. at 5 percent: (a) 157.4

(b) 111.3

(c) 90.8

(d) 64.2

(e) 55.5

(f) 45.3

Analysis of variance: temperature  $P < 0.001$ ; food  $P < 0.001$ ; sex  $P < 0.001$ ; interactions: food  $\times$  temperature  $P < 0.001$ ; sex  $\times$  food  $P < 0.001$ , sex  $\times$  food  $\times$  temperature  $P < 0.001$

### 3. Body weight and silk production

#### a) Body weight of larvae

Weight of mature larvae was higher (4.1 gm.) when reared at 25 °C than at 20 (3.6 gm.) or 30 °C (3.6 gm.) (Table 1).

On grafted varieties the caterpillars did not become so heavy as on seedling mulberry. The two grafted varieties, (body weights being 3.3 & 3.4 gm. for *alba* and *nigra*, respectively) were equally inferior in this respect. The weight of caterpillar on *M. alba* and *M. nigra* seedling was 4.2 and 4.1 gm., respectively (Table 1).

Female larvae always weighed more (4.0 gm.) than male larvae (3.5 gm.) (Table 1). Keeping in view the fact that there is no difference in the speed of development in the two sexes (see Section 1), it would mean that within a given period female caterpillars ingest greater quantity of food than the male caterpillars. This observation stands in good agreement with that of HIRATSUKA (1920) who observed that in the fifth stage female silkworms consumed about 20 per cent more leaves than the male silkworms.

#### b) Silk production

Ignoring the effect of food and sex, the heavier caterpillars spun more silk. When caterpillars were reared at 25 °C the weight of green cocoon and dry silk shell was higher (1.90 and 0.28 gm. respectively) than at 20 (1.63 and 0.23 gm. respectively) or 30 °C (1.56 and 0.21 gm. respectively). Weights were comparatively more at 20 than at 30 °C (Tables 6 & 7). The silk content of cocoon

Table 7

Mean weight of dry silk-shell (*MG*) at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes		All temperatures		Mean	
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male		Female
<i>M. alba</i> seed.	235.3	263.2	318.1	325.9	228.5	263.7	249.2	322.0	246.1	260.6	284.2	272.4
<i>M. nigra</i> seed.	250.4	277.6	307.3	311.8	199.4	241.9	264.0	309.5	220.6	252.3	277.1	264.7
<i>M. alba</i> graft.	205.0	205.2	252.6	229.2	174.8	206.1	205.1	240.9	190.4	210.8	213.5	212.1
<i>M. nigra</i> graft.	206.2	214.0	250.3	248.0	203.3	207.8	210.1	249.1	205.5	219.9	223.2	221.6
S.E. ±			(17.7) <sup>a</sup>				(12.5) <sup>b</sup>			(10.2) <sup>c</sup>		(7.2) <sup>d</sup>
Mean	224.2	240.0	282.0	278.7	201.5	229.8	232.1	280.3	215.6	235.9	249.5	242.7
S.E. ±			(8.8) <sup>e</sup>				(6.2) <sup>f</sup>			(5.1) <sup>g</sup>		

L.S.D. at 5 percent: (a) 34.8 (b) 24.6 (d) 14.1 (e) 16.7 (f) 12.2 (g) 10.0

Analysis of variance: temperature  $P < 0.01$ ; food  $P < 0.001$ ; sex  $P < 0.01$ ; interactions: food  $\times$  temperature  $P < 0.05$ , sex  $\times$  temperature  $P < 0.05$ , sex  $\times$  food  $\times$  temperature  $P < 0.001$

at 30 °C was also less as evidenced by the higher ratio of green cocoon to dry silk-shell weight (7.3) at this temperature than at 20 (7.0) or 25 °C (6.9) (Table 8).

In other insects too, temperature has been observed to have a definite effect on production of silk. *Plutella* caterpillars reared at 18 °C produced significantly more silk than those reared at 25 °C (ATWAL, 1955).

Table 8

Mean ratio of green cocoon to dry silk-shell weight at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	6.52	7.47	5.88	7.54	6.86	7.61	6.99	6.71	7.23	6.42	7.54	6.98
<i>M. nigra</i> seed.	6.67	7.82	6.28	7.16	7.46	7.16	7.24	6.72	7.31	6.80	7.38	7.09
<i>M. alba</i> graft.	5.91	6.94	6.34	8.11	7.28	8.07	6.42	7.22	7.67	6.51	7.70	7.10
<i>M. nigra</i> graft.	6.87	7.79	6.35	7.56	6.79	7.59	7.33	6.95	7.19	6.67	7.64	7.15
S.E. ±			(0.40) <sup>a</sup>				(0.28) <sup>b</sup>			(0.23) <sup>c</sup>		(0.16) <sup>d</sup>
Mean	6.49	7.50	6.21	7.59	7.09	7.60	6.99	6.90	7.35	6.60	7.56	7.08
S.E. ±			(0.20) <sup>e</sup>				(0.14) <sup>f</sup>			(0.11) <sup>g</sup>		

L.S.D. at 5 percent: (a) 0.80 (b) 0.57 (c) 0.40 (d) 0.28 (e) 0.23

Analysis of variance: temperature  $P < 0.01$ , sex  $P < 0.001$ ; interactions: food  $\times$  temperature  $P < 0.01$ ; sex  $\times$  temperature  $P < 0.05$ ; sex  $\times$  food  $\times$  temperature  $P < 0.001$

Food was another factor that effected silk production. Green cocoons and dry silk-shells weighed more when caterpillars were reared on seedling varieties of mulberry than on those from grafted ones (Tables 6, 7); yet, there was no significant difference in percentage silk content of green cocoons raised on any of the foods under trial (Table 8).

Of the seedling varieties green cocoons were observed to weigh more on *M. alba* (1.90 gm.) than on *M. nigra* (1.83 gm.). Among the inferior foods, *M. nigra* grafted produced heavier cocoons (1.59 gm.) than *M. alba* grafted (1.47 gm.). However, these differences within the seedling and grafted varieties are not of much significance because there is only a slight variation in actual silk production (Tables 6 & 7).

Of the two sexes female caterpillars always produced heavier green cocoons (1.87 gm.) than the males (1.53 gm.). However, silk shells from heavier female cocoons did not weigh more (0.25 gm.) than from lighter male cocoons (2.23 gm.) excepting only at 30 °C on seedling varieties (Tables 6 & 7).

#### c) Pupal weight

Live pupae weighed more at 25 °C (1.59 gm.) than at 20 (1.37 gm.) or 30 °C (1.33 gm.), the difference in weights at the latter two temperatures being not significant (Table 3).

Pupae did not become so heavy on grafted varieties of mulberry as on the seedling (1.60 and 1.54 gm. on *alba* and *nigra* seedling respectively) nor were they so heavy on *M. alba* grafted (1.23 gm.) as on *M. nigra* grafted (1.34 gm.) (Table 3).

Female pupae always weighed more (1.60 gm.) than male pupae (1.26 gm.) (Table 3).

#### d) Ratio of live weight to dry matter in pupae

At 20 °C the ratio of live weight to dry matter in pupae was higher (4.92) than at 25 (4.63) or 30 °C (4.67), thereby showing higher water content of pupae

reared at 20 °C. The difference in the ratio at 25 and 30 °C was not significant (Table 4).

On *M. nigra* grafted the ratio was higher (4.89) than on any of the other three foods (4.62 to 4.73). There was no difference in this value between male and female pupae (Table 4).

e) Interaction of temperature, food and sexes

If the influence of temperature and food on the weight of larvae and the weight and water content of pupae is considered in relation to the difference between the sexes, it appears that the females may fulfil their requirements better from a good quality food (leaves from seedling varieties of mulberry) at moderate lower temperatures, whereas males may be able to develop better on poorer food (leaves from grafted varieties of mulberry) at higher temperatures (Tables 1, 3 & 4). It is more economical to rear males (for identification in egg stage see KORSH, 1958), because they consume 20 per cent less food (HIRATSUKA, 1920), produce green cocoons richer in silk content (Table 8) and perhaps can fulfil their requirements better than females under unfavourable conditions of food and temperature.

4. Adult life and fecundity

The results showed that at 25 °C, the insects produced the highest number of eggs (532 per female). The number of eggs laid at 20 °C (451 per female) was higher than at 30 °C (311 per female) (Table 9a). Higher fecundity at 25 than at 20 or 30 °C was always associated with higher larval and pupal weights. This, however, was not observed while comparing the results at 20 and 30 °C, inspite of the fact that pupae contained more water at 20 than at 30 °C (Tables 1, 3 & 4).

Table 9a, b

Average number of eggs per female and percentage successful spinning at different levels of temperature and quality of food

Food	(a) Fecundity				(b) Percentage survival (spinning) <sup>1</sup>			
	20 °C	25 °C	30 °C	Mean	20 °C	25 °C	30 °C	Mean
<i>M. alba</i> seed.	483	568	385	478	88	84	50	74.0
<i>M. nigra</i> seed.	495	625	368	496	90	84	48	74.0
<i>M. alba</i> graft.	431	451	284	388	70	66	34	56.7
<i>M. nigra</i> graft.	395	484	206	361	82	88	72	80.7
S.E. ±		(42.4) <sup>a</sup>		(24.5) <sup>b</sup>				
Mean	451	532	311	431	82.5	80.5	51.0	71.3
S.E. ±		(21.2) <sup>c</sup>						

L.S.D. at 5 percent: (b) 48 (c) 42

Analysis of variance: temperature P < 0.001; Food P < 0.001

<sup>1</sup> Percentage based on 100 insects in each treatment.

The moths lived the longest at 20 °C (10.3 days), followed by 25 °C (8.8 days) and then 30 °C (6.9 days) (Table 10).

Table 10

Mean length of adult life (days) at different levels of temperature and quality of food

Food	20 °C		25 °C		30 °C		Both sexes			All temperatures		Mean
	Male	Female	Male	Female	Male	Female	20 °C	25 °C	30 °C	Male	Female	
<i>M. alba</i> seed.	13.9	9.5	12.0	7.5	6.8	6.4	11.7	9.7	6.6	10.9	7.8	9.3
<i>M. nigra</i> seed.	11.3	10.6	11.1	7.9	8.6	6.1	10.9	9.0	7.3	10.3	8.2	9.2
<i>M. alba</i> graft.	10.7	7.6	8.7	6.3	6.2	6.3	9.1	7.5	6.2	8.5	6.7	7.6
<i>M. nigra</i> graft.	10.3	8.9	11.4	6.7	9.2	5.9	9.6	9.0	7.5	10.3	7.1	8.7
S.E. ±			(1.0) <sup>a</sup>				(0.7) <sup>b</sup>			(0.6) <sup>c</sup>		(0.4) <sup>d</sup>
Mean	11.5	9.1	10.8	7.1	7.7	6.1	10.3	8.8	6.9	10.0	7.4	8.7
S.E. ±			(0.5) <sup>e</sup>				(0.3) <sup>f</sup>			(0.3) <sup>g</sup>		

L.S.D. at 5 percent: (a) 2.0

(d) 0.8

(e) 1.0 (f) 0.7 (g) 0.5

Analysis of variance: temperature  $P < 0.001$ ; food  $P < 0.001$ ; sex  $P < 0.001$ ; interactions: sex  $\times$  food  $\times$  temperature  $P > 0.001$ , sex  $\times$  temperature  $P < 0.05$

Moths laid the highest number of eggs when leaves from seedling varieties of mulberry were used as food. This was associated with higher pupal weights, decreased larval and increased pupal duration (Tables 2, 3, 5 & 9a). It would appear that as compared to the lighter pupae, the heavier ones take longer for transformation into adults which are more fecund and generally longer lived.

Disregarding the effect of temperature, the adult life was the shortest (7.6 days) on *M. alba* grafted and was about the same (8.7 to 9.3 days) on the remaining three foods (Table 10). The interesting observations from these experiments were that the males lived longer than the females and that the females laid the highest number of eggs at 25 °C even though they lived the longest at 20 °C.

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#### Summary

Larvae of *Bombyx mori* LINNAEUS were reared on food of different qualities at different temperatures. — It was found that although the rate of development was highest at 30 °C and lowest at 20 °C, mature larvae and pupae weighed more at 25 °C. Water content of pupae reared at 20 °C was higher than that at the other two temperatures. Larvae reared on leaves from seedling varieties of mulberry developed more quickly than those reared on leaves from grafted varieties. The pupal period, however, was longer on the former than on the latter food. The lower rate of larval development on grafted varieties was associated with decreased larval and pupal weights. Irrespective of temperature and quality of food, larvae and pupae of females were always heavier than those of males.

The rate of survival among caterpillars was lower at 30 °C than at 20 °C or 25 °C. It was also lower on grafted *M. alba* than on any other food.

Silk production by caterpillars was highest at 25 °C and lowest at 30 °C. When larvae were reared on leaves from seedling varieties of mulberry, they produced more silk than



those reared on leaves from grafted varieties. Female caterpillars always produced heavier green cocoons than males. Silk shells from heavier female cocoons, however, did not weigh more than those from lighter male cocoons, except at the unfavourable temperature of 30 °C on seedling foods.

Insects laid the highest number of eggs when reared at 25 °C and the smallest number at 30 °C. There was no difference in larval and pupal weights at 20 °C and 30 °C, but lower fecundity at 30 °C than at 20 °C was definitely associated with the fact that the life of the moths was shorter at the former than at the latter temperature. Insects reared on leaves from seedling mulberry laid significantly more eggs than those reared on leaves from grafted varieties. Adult life was shorter on grafted *M. alba* than on any other food. Generally the males lived longer than the females.

### Zusammenfassung

Larven von *Bombyx mori* LINNAEUS wurden mit verschiedenartiger Nahrung bei unterschiedlichen Temperaturen aufgezogen. — Es wurde festgestellt, daß die Entwicklung bei 30 °C am schnellsten und bei 20 °C am langsamsten verlief, daß aber die ausgereiften Larven und Puppen bei 25 °C am meisten wogen. Der Wassergehalt der gezogenen Puppen war bei 20 °C höher als bei den beiden anderen Temperaturen. Auf Blättern von Maulbeersämlingen gezogene Larven entwickelten sich schneller als auf Blättern von gepfropften Varietäten gezogene. Die Puppenperiode war jedoch bei der ersten Nahrung länger als bei der letzteren. Die langsamere Larvenentwicklung auf den gepfropften Varietäten war mit geringerem Larven- und Puppengewicht verbunden. Unabhängig von der Temperatur und der Güte der Nahrung waren Larven und Puppen von Weibchen immer schwerer als von Männchen.

Die Überlebensquote der Raupen war bei 30 °C niedriger als bei 20 °C oder 25 °C. Sie war ferner bei gepfropftem *M. alba* niedriger als bei jeder anderen Nahrung.

Die Seidenproduktion der Raupen war bei 25 °C am höchsten und bei 30 °C am geringsten. Wenn die Larven auf Blättern von Maulbeersämlingen gezogen wurden, erzeugten sie mehr Seide als bei Aufzucht auf Blättern der gepfropften Varietäten. Weibliche Raupen erzeugten stets schwerere grüne Kokons als männliche. Die Seidenhülsen der schwereren weiblichen Kokons wogen jedoch nicht mehr als die der leichteren männlichen Kokons, außer bei der ungünstigen Temperatur von 30 °C bei Nahrung von Sämlingen.

Die Insekten legten die größte Anzahl von Eiern, wenn sie bei 25 °C gezogen wurden, und die geringste Anzahl bei 30 °C. Das Gewicht der Larven und Puppen bei 20 °C unterschied sich nicht von dem bei 30 °C, aber die bei 30 °C geringere Fruchtbarkeit als bei 20 °C hängt eindeutig damit zusammen, daß das Leben der Motten bei der ersten Temperatur kürzer ist als bei der letzteren. Auf Blättern von Maulbeersämlingen gezogene Insekten legten signifikant mehr Eier als auf Blättern von gepfropften Varietäten gezogene. Das Leben im Reifestadium war auf gepfropftem *M. alba* kürzer als bei jeder anderen Nahrung. Im allgemeinen lebten die Männchen länger als die Weibchen.

### Резюме

Личинки *Bombyx mori* LINNAEUS выращивались при различной пище и при различных температурах. — Отмечалось, что развитие при 30 °C происходило в быстреее время, при 20 °C в самое медленное время, но зрелые личинки и куколки имели при 25 °C самый высокий вес. Содержание воды выращенных куколок было при 20 °C выше чем при обоих других температурах. На листьях сеяниц шёлковицы развивались личинки быстрее чем на листьях от прививочных вариаций. Период куколки была при первой пищи длиннее чем при последней. Медленное развитие личинок на второй пище было связано с меньшим весом личинок и куколок. Независимо от температуры и пищи личинки и куколки самок всегда были тяжелее чем личинки и куколки самцов. — Переживание личинок при 30 °C было ниже чем при 20 °C или 25 °C.

Оно было тоже ниже при прививочных *M. alba* чем у всякой другой пищи. — Производство шёлка было у личинок при 25°C самое высокое и при 30°C самое низкое. Если личинки выращивались на листьях из сеяниц, они производили больше шёлка чем на листьях от прививочных вариаций. Женские личинки производили всегда зелёные коконы тяжелее чем мужские. Гильзы шёлка тяжёлых женских коконов не были тяжелее чем те от мужских, кроме при 30°C и пищи от сеяниц. Насекомые откладывали самое большое число яиц, если их выращивали при 25°C, самое маленькое число при 30°C. Вес личинок и куколок при 20°C не отличался от того при 30°C, но более низкая плодотворность при 30°C чем при 20°C связана несомненно тем, что бабочки при первой температуре живут короче чем при последней. На листьях от сеяниц выращенные насекомые откладывали сигнификантно больше яиц чем выращенные на листьях прививочных вариаций. Жизнь в стадии зрелости была на прививочных *M. alba* короче чем на другой пище. В общем самцы жили длиннее чем самки.

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