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STUDY INTO THE EFFECT OF DIFFERENT TEMPERATURES ON THE MAIN PRODUCTIVE CHARACTERS OF THE CHINESE SILKWORM, *BOMBYX MORI* L. (LEPIDOPTERA: LYMANTRIIDAE) LARVAE IN EGYPT

Introduction. Sericulture in Egypt dates back to the 18th century, when mulberry cultivation was introduced, and the first silkworm rearing has been performed in Egypt since then. The number of farmers involved in sericulture in Egypt is about 3000–3500, more than 50 % being women involved in hand reeling and carpet manufacture.

Mulberry cultivation is considered to be one of the most profitable crops in Egypt, however Egypt imports about 50 tons of low grade yarns annually.

Due to the high demand for silk-yarn in Egypt and the need in reducing imports, it is necessary to increase production. As Egypt is located in the subtropical zone, tropical mulberry varieties such as Canva-2 sprout throughout the year making it is possible to produce several generations of the silkworm per year.

However one of the problems in multiple rearing is temperature control and its effect on the silkworm development and productivity.

Body temperature of the silkworm larva varies with the ambient temperature (Reali *et al.*, 1990), and influences the physiological activities, food intake, and silk production parameters (Tzenov, Mladenov, 1996; Maniraju *et al.*, 1999).

The effect of temperature during rearing on survival, growth, cocoon production and silk quality have been studied by many researchers (Relation …, 1958; Ueda, Marizuka, 1962; Yakomoto, Fujimaki, 1962; Ueda, 1963; Verma, Atwal, 1967; Sigematsu, Takeshita, 1967; Rapusas, Gabriel, 1976; Maniraju, 1995).

The influence of temperature on the silkworm depends on a number of factors, such as the stage of metamorphosis, genotype, nutrition, humidity, and air velocity (Petkov, 1972; Karaivanov, 1989; Manjula, 1990; Takagishi, Ueda, 1991; Krishnaswamy, 1992; Shirota, 1992).

According to G. P. Singh *et al.* (Young …, 1998), infant silkworms require a comparatively higher temperature due to which mulberry leaf ingestion, digestion and metabolic rate is increased considerably.

M. S. Jolly (1987), S. R. Ullal and N. Narisimhana (1987) reported that the early instar larvae are resistant to high temperature (26–28°C), this temperature also favorable for their healthy growth.

P. Tzenov (1996b) studied the effect of low (18°C), moderate (23°C) and high (28°C) temperatures on the dry matter content in food of the fifth instar larvae in two silkworm pure lines, namely Super1 and Hessa2, of Japanese and Chinese origins respectively. The results obtained indicated that low temperature rearing increases the quantities of food ingested and digested, while high temperature produces the opposite effect, i. e. food digested is utilized more effectively compared with the low and moderate temperature rearing.

Taking in consideration the considerable influence of temperature on the silkworms larvae, it is necessary to determine an optimum thermal regime for the different highly productive breeds when feeding with quality mulberry leaves.

The present study has been carried out to analyze in detail the effect of two different temperature regimes on the main productive characters in various instars in Egypt.

Materials and methods. The experiments were made in Agromier Co. mulberry plantation and rearing houses located in Asyut province of Egypt 320 km to the south of Cairo in a desert area in 1997–1998. The plantation was irrigated by the Nile water regularly.

Mulberry plantation is mainly of Kokuso-27 and Canva-2 varieties shaped in bush, and annual pruning was done in such a way that only 3 buds were left.

Fertilizers applied to the mulberry garden: NPK (Nitrogen, Phosphorus, Potassium) at a dose of 300:150:120 units per hectare with micro- and secondary nutrients.

As secondary nutrients we added Calcium (Ca) and Sulphur (S) within macro-fertilizers (NPK), and Magnesium that is added with micronutrients.

Chlorine is added with the macronutrients.

The recipe for preparing the mixture of micronutrients* was as follows (Table 1):

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Table 1. Recipe for preparing the mixture of micronutrients

Compound	Chemical formula	Amount, kg/ha	Concentration, %
Magnesium Sulphate**	$MgSO_4$	50	Mg – 11
Manganese Sulphate	$MnSO_4$	30	Mn – 27
Ferrous Sulphate	$FeSO_4$	10	Fe – 19
Zinc Sulphate	$ZnSO_4$	10	Zn – 35
Copper Sulphate	$CuSO_4$	1.5	Cu – 28
Boric Acid	H_3BO_4	2	B – 17
Ammonium Molybdate	$(NH_3)_2MoO_4$	1	Mo – 54

* The author previously tested the amounts and the percentage of the nutrients.
** Magnesium is a secondary nutrient.

The fertilizers were uniformly spread in trenches after each branch harvest, immediately before the 3rd irrigation.

Rearing houses were equipped with automatic temperature and humidity control devices. In the control groups, the rearing was done at standard regimes of temperature, humidity, illumination, and air speed (Table 2) described in Japanese, Korean, Indian, Bulgarian and Ukrainian literature (Ajuzawa, 1972; Zlotin, Bolavin, 1988; Handbook …, 1989; Sericulture …, 1990; Krishnaswamy, 1993).

Table 2. Standard regimes of temperature, relative humidity, illumination, and air speed during the silkworm rearing

Age	Temperature, °C	Relative humidity, %	Illumination, lx	Air speed, m/sec
1 and 2 instars	27	85	25	0.1
3 instar	25	80	25	0.1
4 and 5 instars	23	70	25	0.3
Mounting and spinning	27	60	25	0.5

Rearing was performed using plastic trays (70×40×30 cm) accommodating 100 larvae counted immediately after the 2nd moult. During each experiment all the larvae were fed with equal amounts of leaves of the same variety. Bed spacing was performed daily before morning feeding, and bed cleaning was performed after each moult.

Bottlebrush type plastic mountage were used for mounting.

11 breeds were used throughout the experiments, and every breed was tested in 4 replicates of 100 larvae counted immediately after the 2nd moult. The breeds were obtained from the Agromier Co. germ bank and represented 3 Chinese, 3 Japanese, 3 European and 2 egg sex-limited breeds. All breeds were of different geographical origins, bred and selected in Agromier Co. germ bank and stored under these codes.

We implemented house disinfections with 5 % solution of chlorinated lime (bleaching powder) ($CaOCl_2$) in the W/V spray form, and on the next day – with 0.2 % solution of acetic acid (CH_3COOH) in the spray form.

Also we performed egg disinfections with 0.04 % solution of acetic acid for 15 minutes.

Bed and larvae disinfections were performed after every moult when 95 % of larvae finished their moulting, a special powder for bed disinfections was applied uniformly at the rate of 250 g/m^2 of bed in young instars and 500 g/m^2 in late instars. The powder was applied once on the 4th day of the fifth instar before the 1st morning feeding when there were no edible leaves in the beds. The bed disinfectant ingredients were as follows: calcium oxide – 88 %, bleaching powder – 10 %, benzoic acid – 1 %, Diathane M 45 – 1 %.

We formed the following test groups:

Experiment 1. All instars reared at 23°C.
Experiment 2. All instars reared at 27°C.
Experiment 3. 1–3rd instars reared at 23°C, 4–5th instars reared at 27°C.

During moulting the relative humidity was reduced to 50 %, and a nylon cover was removed from the beds of the young instar larvae maintaining the original temperature. We kept illumination, relative humidity and air speed in control and test groups constant.

During the years of 1997 and 1998, 4 test rearings per year of all breeds were conducted in 4 replicates of 100 larvae each, and the cocoon collected were checked for the main productive characters. The data were statistically analyzed using the standard methods.

Results and discussion. From Table 3 it is evident that the temperature regimes gave the same influence on the test breeds irrespective of their origin. The average data for the 2 years show no effect of the rearing temperature regimes on the pupation ratio. It means that temperature from 23 to 27°C are the optimum range for normal development of larvae and accordingly show a high survival ratio. B. Maniraju *et al.* (1999) reared the silkworm breeds Pure Mysore (multivoltine) and NB4D2 (bivoltine) under constant temperature of 26, 28, 30 and 32°C during young and late instars with all different combinations. He reported that the low temperature of 26°C throughout the rearing favored the higher silk conversion with better survival in bivoltine breeds (87 %). Our results confirm his finding with even at a lower temperature (23°C).

Table 3. Effect of different temperature regimes on the main productive characters of the different silkworm breeds

Groups	Breeds										
	E2	E6	E15	E1	E5a	E14	E4b	E8	E9	E22	E23
Pupation, %											
Experiment 1	98.66	98.58	99.04	98.51	98.72	98.73	98.12	98.44	98.58	98.00	98.47
Experiment 2	98.74	98.43	98.23	98.40	98.40	98.40	98.30	98.36	98.45	97.69	98.18
Experiment 3	98.32	98.31	98.25	98.29	98.40	98.22	98.29	98.17	98.40	97.58	98.06
Control	98.74	98.59	98.98	98.84	98.41	98.73	98.62	98.37	98.58	98.03	98.64
Duration of the larval stage, hr											
Experiment 1	705*	705*	705*	681*	681*	681*	705*	705*	705*	705*	705*
Experiment 2	657*	657*	657*	633*	633*	633*	657*	657*	657*	657*	657*
Experiment 3	657*	657*	657*	633*	633*	633*	657*	657*	657*	657*	657*
Control	681	681	681	657	657	657	681	681	681	681	681
Cocoon weight, g											
Experiment 1	2.334*	2.334*	2.362*	2.378*	2.462	2.172	2.298*	2.177	2.093	2.033	2.010
Experiment 2	2.106*	2.063*	2.002**	2.097*	2.001**	1.977	1.971*	1.935	1.883*	1.827	1.854
Experiment 3	2.183	2.181	2.129	2.195	2.205	2.065	2.081	1.990	1.928	1.871	1.877
Control	2.253	2.199	2.232	2.270	2.380	2.109	2.174	2.078	2.009	1.952	1.919
Shell weight, g											
Experiment 1	0.541	0.554	0.532*	0.507	0.559	0.499	0.503	0.527	0.519	0.442	0.477
Experiment 2	0.497*	0.499*	0.448	0.457	0.461*	0.461	0.441	0.473	0.467	0.405	0.444
Experiment 3	0.509	0.522	0.477	0.471	0.506	0.479	0.462	0.484	0.475	0.414	0.449
Control	0.523	0.525	0.497	0.483	0.544	0.486	0.479	0.503	0.494	0.430	0.458
Silk ratio, %											
Experiment 1	23.16	23.75	22.14	21.33	22.73	22.95	21.87	24.17	24.78	21.72	23.70
Experiment 2	23.43	24.17	22.53	21.76	23.00	23.29	22.35	24.44	24.76	22.16	23.95
Experiment 3	23.31	23.93	22.38	21.47	22.94	23.18	22.20	24.34	24.62	22.13	23.92
Control	23.20	23.86	22.25	21.27	22.87	23.02	22.04	24.21	24.58	22.00	23.87

* $P<0.05$, ** $P<0.01$, *** $P<0.001$.

Our results showed a one-day increase of the larval stage duration in Experiment 1 and a one-day decrease of this character in Experiment 2 and Experiment 3 compared with the control. Other authors (Venugopalpilli, Krishnaswamy, 1987; Hanumappa, 1988; Bashkar *et al.*, 1999) detected a direct correlation between metabolic responses of the silkworm and temperature, which is in confirmation with the results obtained by us in the present study. The data for the cocoon weight and shell weight prove that most of the tested breeds show a significant increase for both characters in Experiment 1, a decrease in Experiment 2, and no significant change in Experiment 3 compared with the control. The highest and proven values are demonstrated in Experiment 1 that exceeds Experiment 2, Experiment 3 and control by 0.156–0.461 g, 0.107–0.257 g, and 0.036–0.135 g (11.22–23.04 %, 5.18–11.66%, and 2.99–6.14%) respectively.

Similarly, the highest values for shell weight were recorded in Experiment 1, exceeding Experiment 2, Experiment 3 and control by 0.033–0.098 g (7.43–21.26 %), 0.020–0.055 g (4.18–11.53 %), and 0.012–0.035 g (2.97–7.04%) respectively. The breeds of the Japanese origins tended to give a comparatively higher increase of shell weight in Experiment 1 compared with the breeds of the Chinese origins.

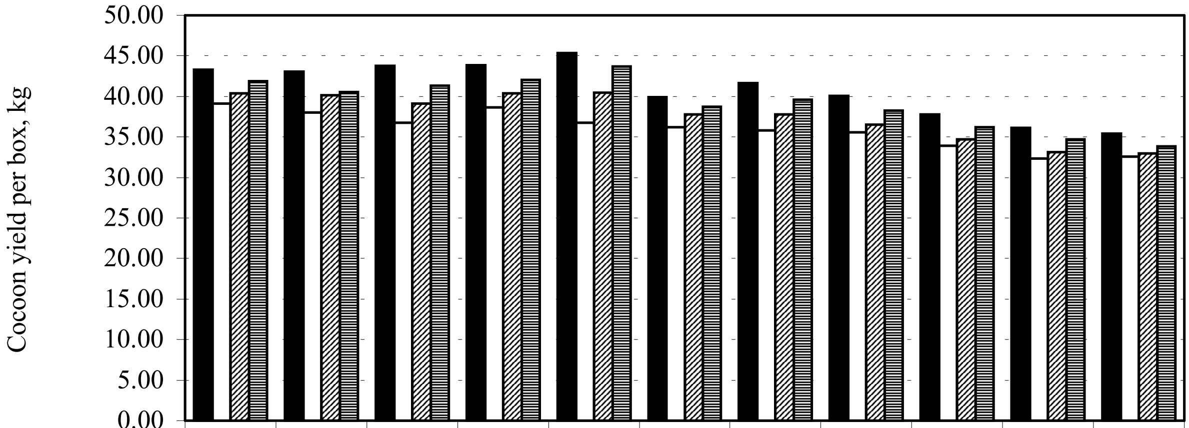
According to P. Tzenov (1996a, 1996b), P. Tzenov and G. Mladenov (1996), low (18°C) and moderate (23°C) temperature fifth larval instar rearing increased the quantities of food ingested and digested, while the high temperature produced the opposite effect. Low temperature fifth instar rearing increased the cocoon weight, shell weight, cocoon yield per box of eggs, moth emergence percentage and number and weight of eggs per laying. Also S. Ueda *et al.* (1969) reported that there were not any significant differences concerning the growth rate, cocoon weight, shell weight and fecundity between rearing of the fifth instar silkworm larvae at 22°C and 26°C, when the larvae are fed with good quality mulberry leaves.

According to S. Ueda and K. Suzuki (1967), Jun Liang Xu and Xiao Feng Wu (1992), E. Maniraju (1995), with the increase of the temperature from 20 to 30°C, the conversion of mulberry leaves to silk decreases.

All these findings are in agreement with our results in the late instars. However in the young instars, rearing temperature results are contrary to Y. Tanaka (1964) who reported that the temperature during young instars (I, II, III) affects the cocoon characters (cocoon and shell weight) considerably, the optimum being 28°C, and the worst – 23°C. He also recorded the highest shell weight ratio with the lowest larval loss at 28°C. Our results can be explained by the finding of C. D. Basavaraju *et al.* (1998) who made a conclusion that the temperature influences the metabolic activities of larvae depending not only on an instar but also on a breed. Also it was reported by G. P. Singh *et al.* (Young …, 1998) that if young silkworms are reared under high temperature of 27–28°C, it is absolutely necessary to feed them with rich nutritive leaves in sufficient quantity. If the leaf quality and quantity are insufficient, it is necessary to lower the temperature by one degree in every instar. Which means that the infant silkworms, similar to grown silkworms have better utilization of food at lower temperature.

From the data present in Table 3 we can notice that there was no significant effect of the rearing temperature on the shell weight ratio. In our opinion this may be explained by the fact that the application of micro- and secondary nutrients gave equal influence on increasing the cocoon and shell weights. However a slight increase is noticed in Experiment 2 with higher temperature rearing, which can be explained by the fact that the food was utilized more effectively under the high temperature than under low and moderate temperatures, as reported by P. Tzenov (1996b).

Data from Fig. 1 show the generalized results: the cocoon yield per box reveal a significant increase over the control under the low temperature regime (23°C) throughout the whole larval period in Experiment 1 and a significant decrease under the high temperature regime (27°C) throughout the whole larval period in Experiment 2, as expected. However a slight decrease in the cocoon weight and in pupation ratio manifested themselves as a significant decrease in the cocoon yield per box in Experiment 3 where the young instars were reared at 23 C, and late instars – at 28 C. Excellence of tested temperature regime to Experiment 1, Experiment 2 and control was between 2.85–8.75 kg (8.75–23.46 %), 2.16–4.87 kg (5.72–12.03 %), and 0.50–2.05 kg (1.43–4.92%) respectively. Similarly to cocoon weight character, the highest cocoon yield per box was recorded in breeds of the Japanese and Chinese origins.



	E2	E6	E15	E1	E5a	E14	E4b	E8	E9	E22	E23
■ Experiment 1	43.32	43.07	43.75	43.87	45.36	39.93	41.66	40.08	37.74	36.11	35.42
□ Experiment 2	39.12	38.01	36.78	38.64	36.74	36.23	35.80	35.60	33.91	32.35	32.57
▨ Experiment 3	40.38	40.13	39.12	40.40	40.49	37.77	37.79	36.54	34.70	33.09	32.94
▤ Control	41.85	40.57	41.31	42.01	43.71	38.76	39.62	38.24	36.23	34.67	33.87

Breeds

Fig. 1. Effect of different temperature regimes on the cocoon yield per box in the different silkworm breeds.

Conclusions. The lower temperature 23°C during the whole larval period instead of the standard regime (27°C for young and 23°C for late instars) leads to higher cocoon weight, cocoon shell weight and cocoon yield per box, by 0.063–0.135 g (2.99–6.14 %), 0.012–0.035 g (2.79–7.04 %), and 1.24–2.67 kg (2.98–6.14%) respectively. However the rearing temperature does not affect either the shell or the pupation ratio, indicating that this range (23–27 C) is optimum for the silkworm rearing. In general, higher values and proven differences were obtained in breeds of the Japanese and Chinese origins, and lower ones – at genetically sex-limited breeds.

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ИЗУЧЕНИЕ ВЛИЯНИЯ РАЗЛИЧНЫХ ТЕМПЕРАТУР НА ГЛАВНЫЕ ПРОДУКТИВНЫЕ ПРИЗНАКИ ЛИЧИНОК ТУТОВОГО ШЕЛКОПРЯДА *BOMBYX MORI* L. (LEPIDOPTERA: LYMANTRIIDAE) В ЕГИПТЕ

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Р Е З Ю М Е

Проводилось изучение влияния различных температур (23 и 27°С) на главные продуктивные признаки личинок тутового шелкопряда 11 пород, имеющих различное происхождение и характеристики, в Египте. Установлено, что различные температурные режимы не оказывали значительного воздействия на степень окукливания и шелконосность. Продолжительность гусеничной стадии была короче при более высоком температурном режиме, но вес кокона и оболочки кокона, а также урожай сырых коконов с одной коробки яиц были выше при низкой температуре (23°С). С целью увеличения урожая коконов данный температурный режим (23°С в течение всего личиночного периода) рекомендуется для выращивания высокопродуктивных чистых пород при условии обеспечения личинок высококачественным кормом.

3 табл., 1 рис., 36 назв.