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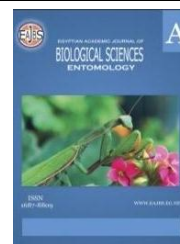
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Adapting Grown Silkworm, *Bombyx mori* L., Rearing Techniques Under Temperate Conditions

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ABSTRACT

Silk, produced by the mulberry silkworm, *Bombyx mori* L. is a highly valuable commodity utilized in fabrics, textiles, cosmetics, and military industries. The larvae of silkworms are influenced by multiple factors associated with climate change. Controlling factors surrounding silkworm larvae is taken into consideration to ensure the sustainability of silk output. Temperature degrees and humidity are serious elements that control natural silk production. Four treatments applied for whole instars (enveloped type 1, enveloped type 2, normal silkworm rearing, and mixing plastic sheet and paraffin paper) were evaluated using three imported hybrids of silkworm, *Bombyx mori* to enhance rearing techniques; also same treatments were applied for young instars of silkworm larvae. Seventeen traits were taken into consideration. The results clarified that treatments of enveloped type 1 and 2 were the best treatments, whereas safest temperature and relative humidity. Also, the safe freshness of mulberry leaves for a long time to be available for feeding larvae.

INTRODUCTION

Sericulture is a method that contributes to sustainable development in some countries by transforming cocoons into natural silk. Silk is a precious fibre renowned as the "Attire of the Heavenly People" and embodies splendour, affability, refinement, and softness. There are several obstacles facing the sustainability of silk output. Environmental elements are one of the factors that are most deeply influential in silk yarn production (Fatima *et al.* 2022). The Egyptian climatic condition is suitable for rearing silkworms, *Bombyx mori* L., but silk production from the box is lower than in the advanced countries in sericulture. The obstacles facing sericulture in Egypt are season, mulberry cultivation, silkworm diseases, and environmental factors. The climate has an unfavourable influence on sericulture as reported by (Bhattarcharjya *et al.*, 2020 & Bhat *et al.*, 2024). Global warming is expected to cause direct and indirect impact on sericulture (Hariharan *et al.*, 2024). Efforts and attempts of silkworm scientists by various research centres lead to the development of rearing techniques and all factors affecting silk production to enhance the rearing conditions. The problems facing the Sericulturists, coupled with problems of environmental factors (high temperature and low humidity), load of diseases dominant in the temperate region, result in a decline in cocoon yield (Sudan *et al.*, 2023). Silkworm larvae are reared at the

suitable temperature degrees and relative humidity percentages reducing mortality ratio and increasing pupae weight, but silkworm larvae with un-optimal temperature degrees and humidity, cocoon crops per box can decrease by 15-30 kilograms, and quality can be 14% lower (Bekkamov and Samatova, 2023). Grown silkworms were more tolerant of temperatures 17°C & 33°C, whereas 43°C proved deadly. All of the issues created by these adverse conditions may be readily rectified by rigorously adhering to the suggested silkworm-rearing method. This experiment aimed to develop the rearing technique to face the low relative humidity and degrees of temperature during the Spring season to increase cocoon production.

MATERIALS AND METHODS

Three mulberry silkworm, *B. mori* hybrids were imported from Bulgaria are used in this experiment: G₂ X K₂ X H₁ X KK Coded as (G), KK₁ X K₂ X H₁ X KK Coded as (K) and H₁ X KK X V₂ X G₂ Coded as (H). There are four techniques applied for young instars only and the same treatments were applied for the whole instars of the silkworm larvae. Treatments through young instar only are Enveloped type1 (Silkworms reared using rearing stands enveloped by plastic sheets and larvae reared on plastic sheets coded as (C) treatment, Enveloped type 2 (Silkworms reared using rearing stands enveloped by plastic sheets and larvae reared on paraffin paper coded as (P) treatment, Normal silkworm rearing (the larvae were reared on a polythene sheet and covered with the same plastic sheet coded as (N) treatment, and Mixing plastic sheet and paraffin paper (Silkworm worm were reared with a plastic sheets and coated with paraffin paper coded as (M) treatment. The former treatments are applied during the first three instars only, and during the fourth and fifth instar, regular methods were carried out i.e. the plastic envelope and coverage were removed and the silkworm larvae reared under the rearing room temperature and humidity. The previous four techniques Enveloped type1 (C), Enveloped type 2 (P), Normal silkworm rearing (N), and Mixing plastic sheet & paraffin paper (M) were applied through young instar and grown silkworm instars (whole instars) i.e. the plastic envelope and coverage were continuous till the mountage started. The experiments were carried out at Qanater silk station in (Qalubeiya governorate). Each treatment was represented by three replicates. Each replicate has 500 larvae reared in trays measuring (60 X 90 X 10) cm. The degrees of temperature & relative humidity were registered inside each treatment separately. Also, temperature & relative humidity was tabulated for rearing room. The larvae of silkworm were fed a mulberry variety of *Morus alba* var kokous-27 four times daily. Chopped mulberry leaves were offered during the young instars. Wit foam strips are used to increase the humidity during young instars and removed through fasting and after the third moult. Complete mulberry leaves were offered for the grown instars. The disinfectant was applied after every moult on special days as described by Hosny *et al.*, (2002). Larvae after maturation were put in the collapsible frames for mountage and the cocoons were collected after 7 days. The collected data are registered for all the treatments viz., fifth (5th LD) and whole larval duration (WLD), larval mortality for young (YLM) and grown larvae (GLM), fourth growth rate (4th GR) and fifth growth rate (5th GR), cocooning percentage (CP), pupation ratio (PR), double cocooning % (DCP), cocoon numbers per litter (C/L). Also, cocoon weight (CW), shell weight (CSW), pupa weight (PW), cocoon shell rate (CSR), and productivity of silk (SP) were recorded for females and males. Cocoons crop by number (Crop/No) and weight (Crop/W) per 10,000 larvae were registered.

Growth rates were calculated as mentioned by WaldBauer, (1968) as follows:

$$\text{Growth rate} = \frac{w_2 - w_1}{w_1}$$

Where:

W₁: Initial weight of the larvae (g)

W₂: Final weight of the larvae (g)

The pupation % was registered according to the following formula by Lea (1996):

$$\text{Pupation ratio (\%)} = \frac{\text{No. of healthy pupae}}{\text{Correct basic No. of examined}} \times 100$$

Silk productivity was calculated by the following equation of Iyengar *et al.* (1983):

$$\text{Silk productivity (cg/day)} = \frac{\text{Cocoons shell weight (cg)}}{\text{Fifth instar duration (day)}}$$

Where cg: Centigram

All obtained data were collected and analyzed with the SAS program (SAS, 1998).

RESULTS AND DISCUSSION

Data in Figure 1, showed the minimum, maximum, and average of temperature degrees and relative humidity percentages for all treatments as well as the rearing room during the young instar treatments. Data showed that both room temperature and relative humidity recorded their lowest values. It can be concluded that the treatments enhanced the temperatures and relative humidity.

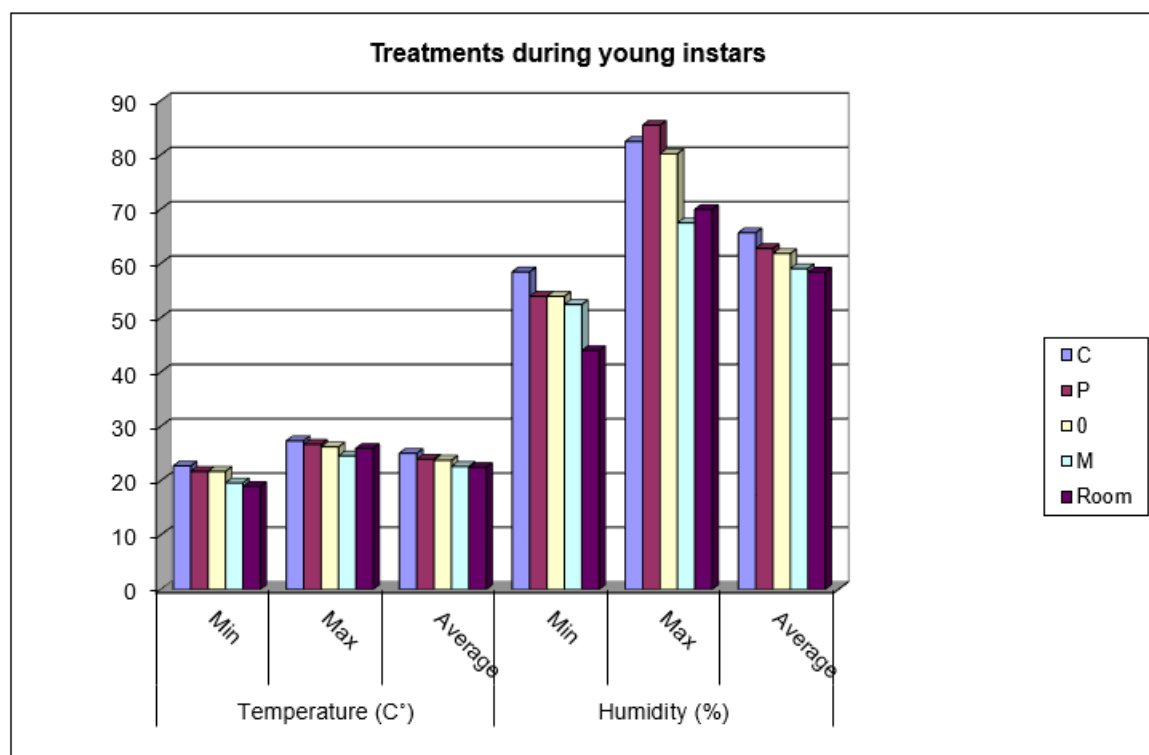


Fig. 1. Minimum, maximum, and average of temperature degrees and relative humidity percentages.

Figures 2-5 illustrate the registered temperature and relative humidity of each treatment during the young instar for the rearing cycle. Results discerned those treatments of C and P recorded near optimum temperature degrees and relative humidity percentages. So, treatments of C and P may be improving the characters of silkworm, *B. mori*, because they enhance the climatic conditions. As well as keeping the freshness of mulberry leaves, more time is available for feeding the silkworm larvae.

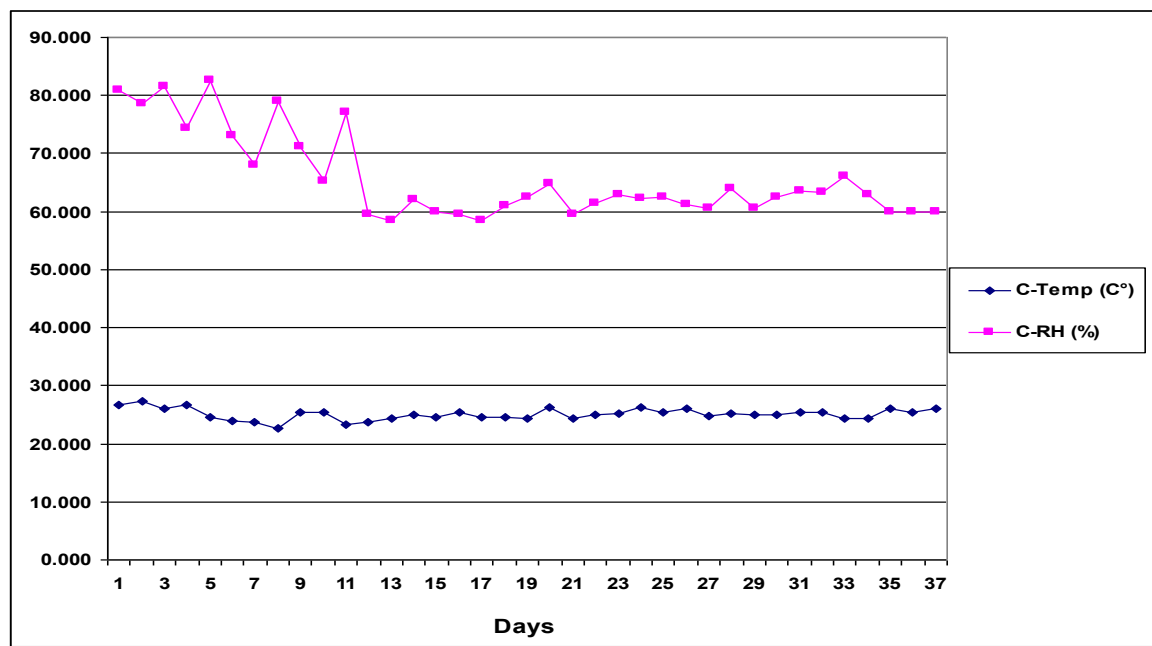


Fig.2. Temperature degrees and relative humidity inside the C treatment during the young instars.

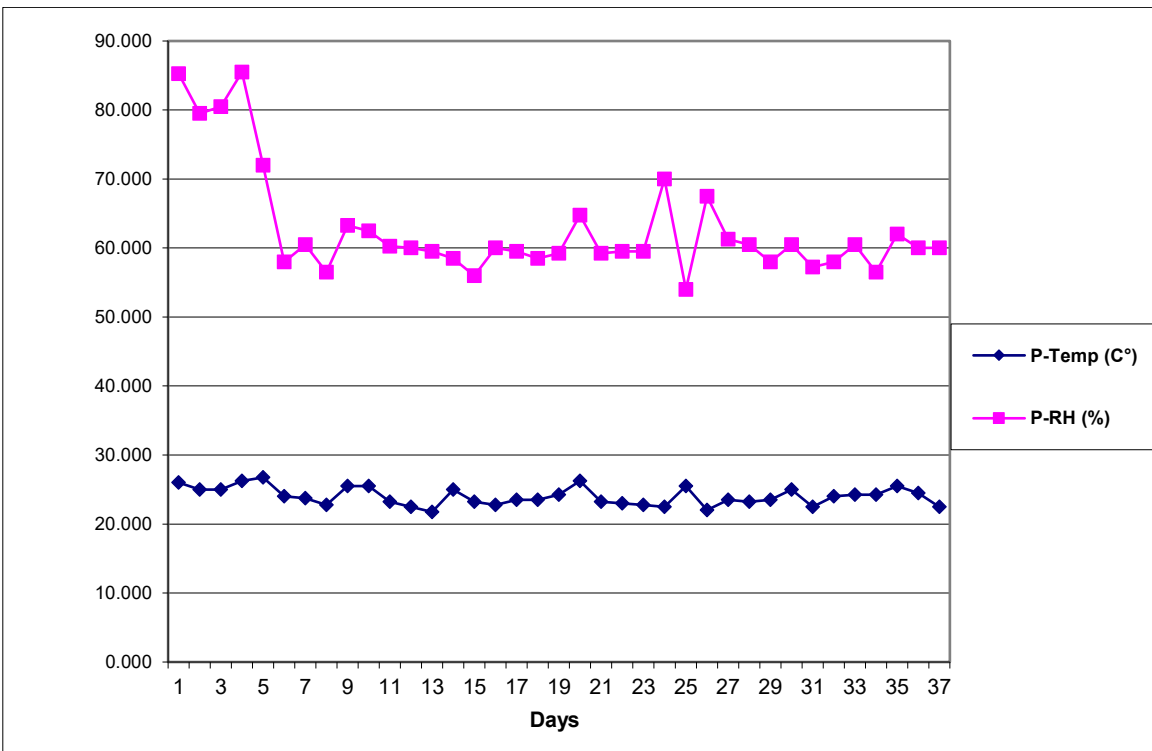


Fig.3. Temperature degrees and relative humidity inside the P treatment during the young instars.

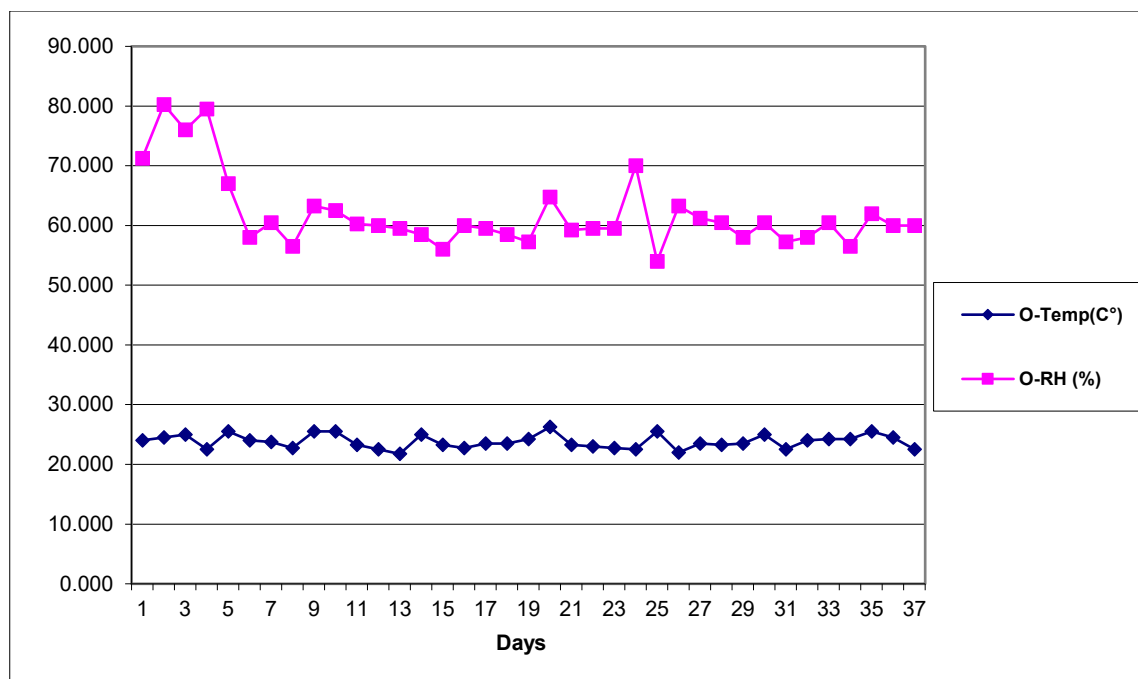


Fig.4. Temperature degrees and relative humidity inside the O treatment during the young instars.

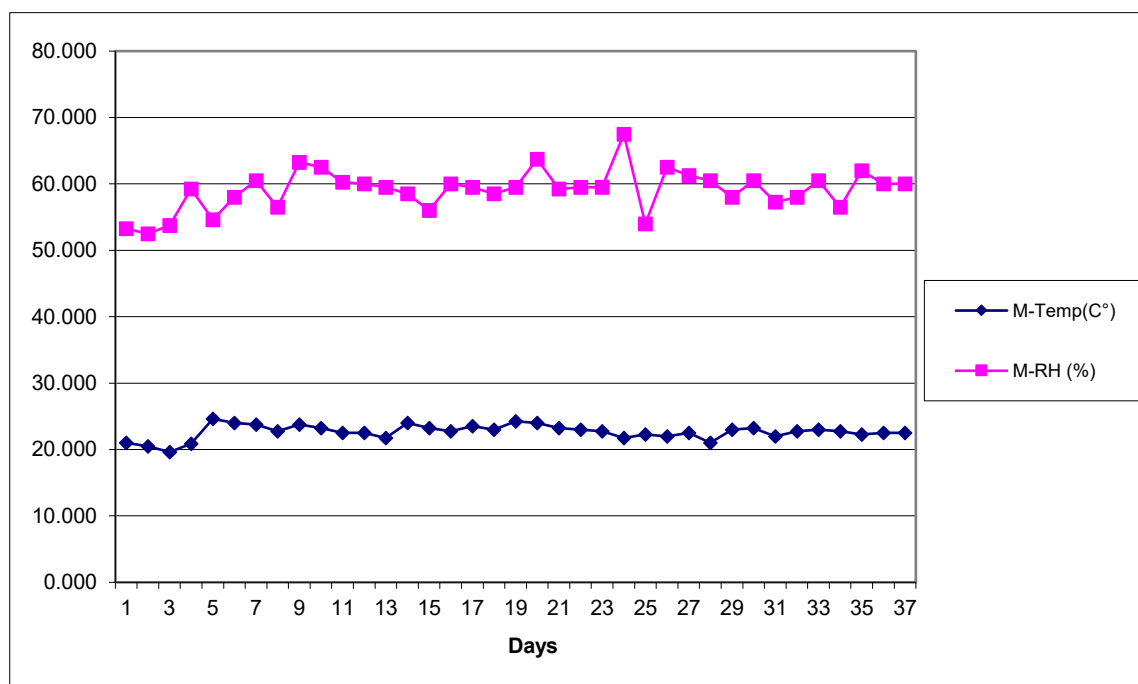


Fig.5. Temperature degrees and relative humidity inside the M treatment during the young instars.

Figure 6 revealed the minimum, maximum, and mean temperature degrees & relative humidity percentages for treatments through whole instars. It is recognized that all treatments have higher temperature and relative humidity percentages, so the treatments save the best temperature and relative humidity compared to rearing room conditions. These may lead to improving the traits of the mulberry silkworm.

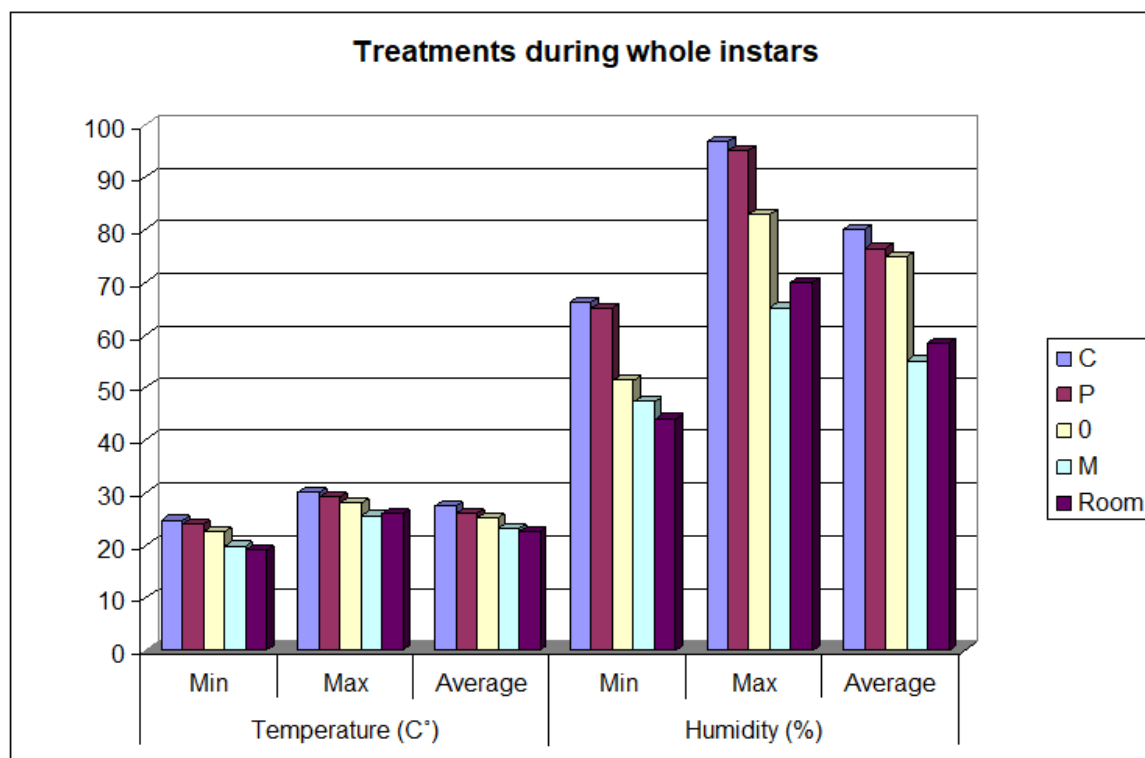


Fig. 6. Minimum, maximum , and average of temperature degrees and relative humidity percentage

Data described in Figures 7- 10 showed the degrees of temperature and relative humidity percentages to the treatments of whole larval duration. Results explained that treatments of C and P have higher temperatures and relative humidity. So, these treatments save the best conditions for the larvae of silkworms as well as keep the freshness of mulberry leaves for a long time. These results are consistent with the data of Krishnaswami (1990) noted that the suitable temperature degrees and relative humidity percentages needed for the normal and developed young instars range from 27-26°C and 80- 90%. The grown silkworm ranged from 23-25 °C and 70-75%.

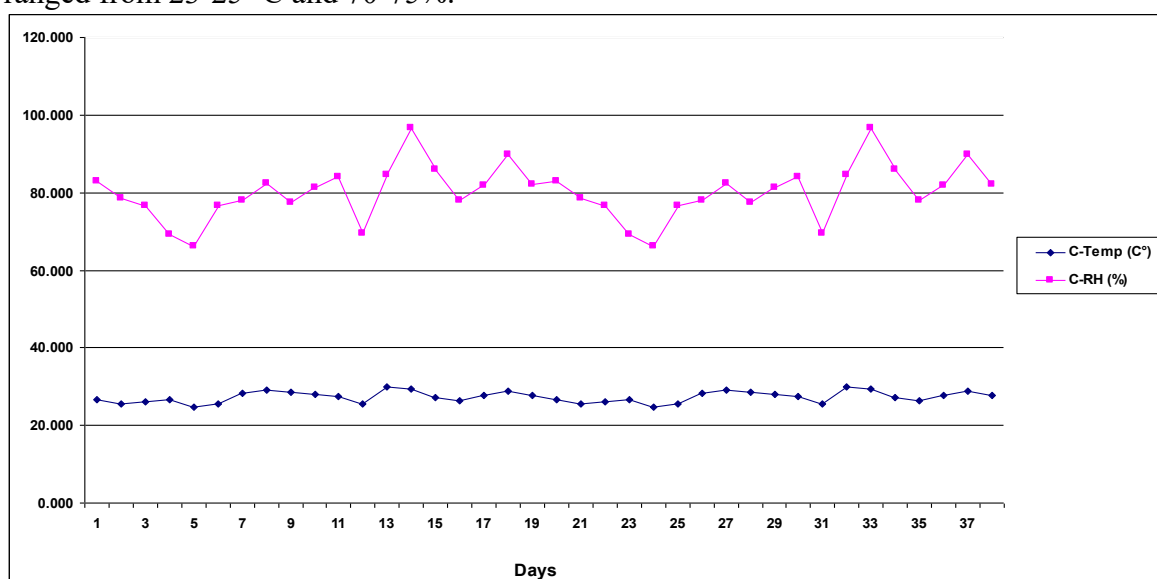


Fig.7. Temperature degrees and Relative humidity inside the C treatment during the whole instars.

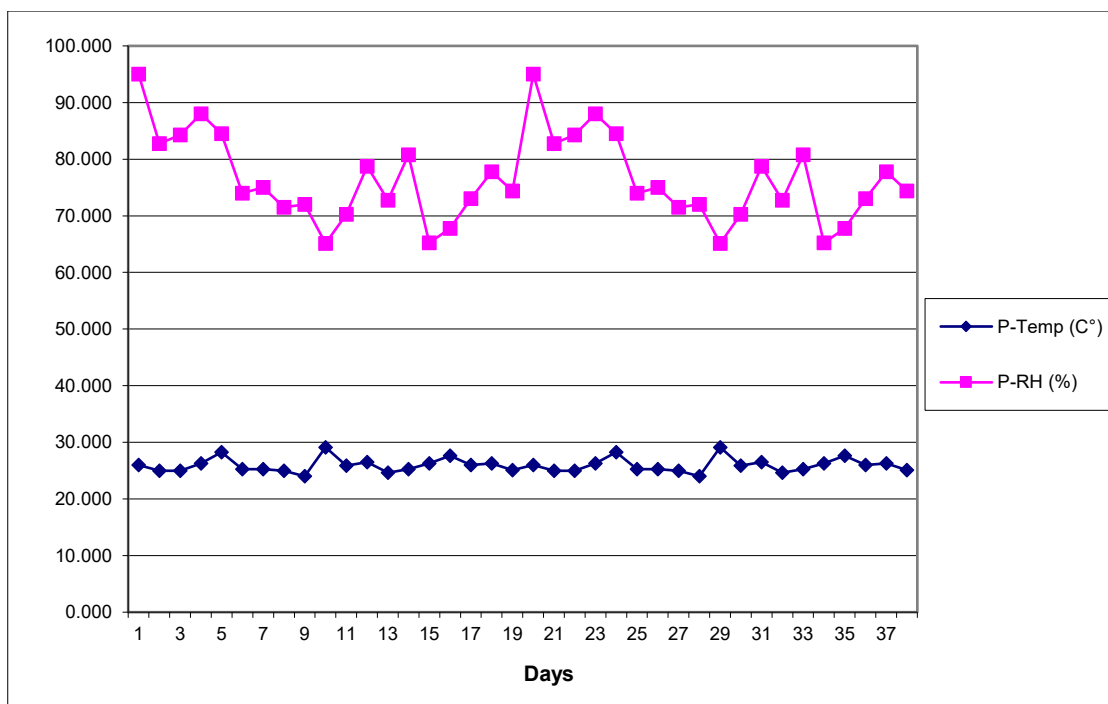


Fig.8. Temperature degrees and Relative humidity inside the P during the Whole instars.

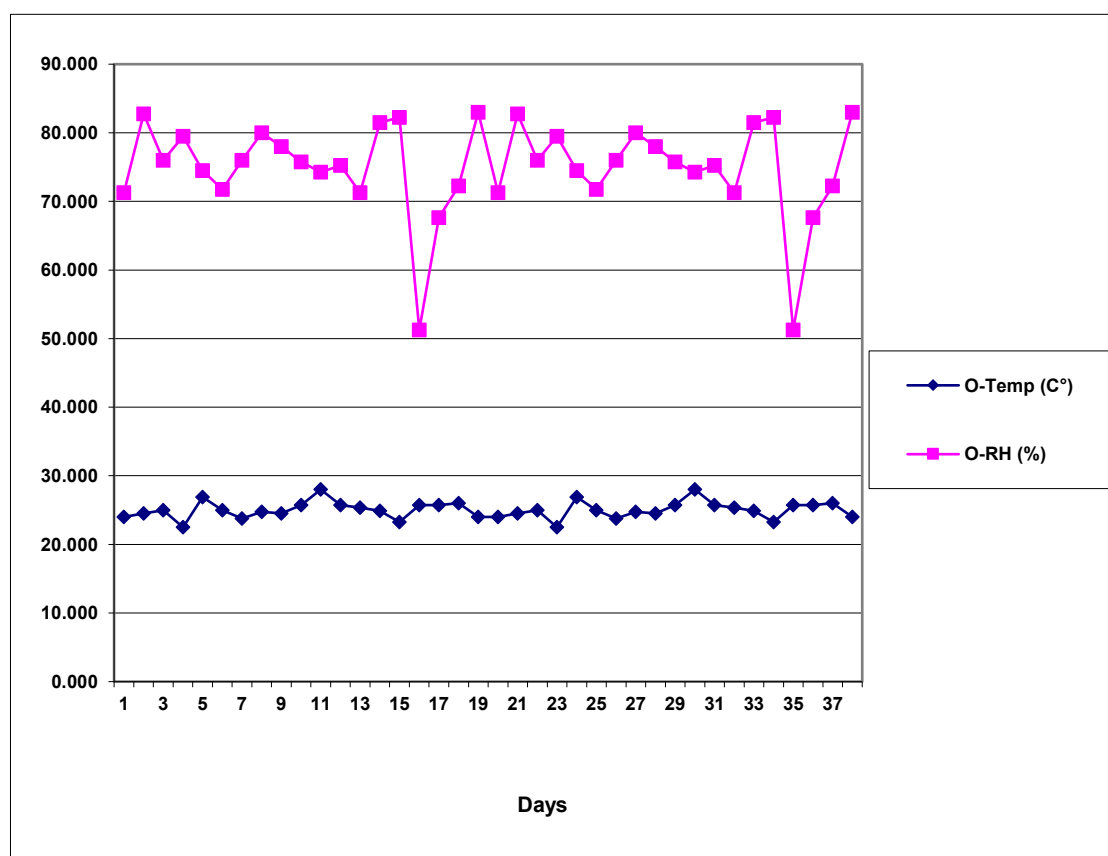


Fig.9. Temperature degrees and Relative humidity inside the O treatment during the whole instars

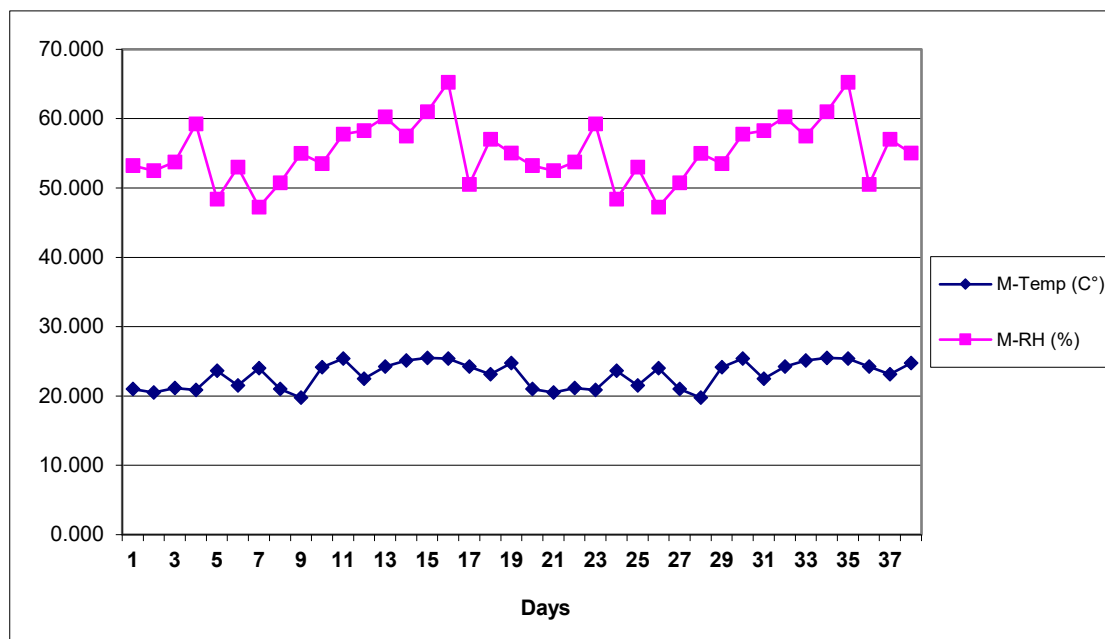


Fig.10. Temperature degrees and Relative humidity inside the M treatment during the whole instars.

Differentiation between some rearing silkworm techniques treatments in Table 1 data revealed highly significant differences between treatments for most traits. Treatments of enveloped type 1 (C) and enveloped type 2 (P) have better mean values for most characters under study. These results agree that maybe the enveloped trays with plastic sheets save temperature degrees, and humidity percentages within a range that is suitable for the survival and development of silkworm larvae. These findings are consistent with those observed by (Datta *et al.* 2013, Neelaboina *et al.* 2019, Sudan *et al.* 2020 and Fouad, 2020) they reported, chawki rearing practices using box, wrap-up and polythene sheets methods resulted in much superior to open type of shelf rearing by providing optimal microclimatic conditions of temperature, moisture content and moisture retention capacity for five mulberry varieties through young and late ages for larval growth leads to improved economic performance.

Table .1. Differentiation between treatments technique of rearing silkworm *B. mori* L.

Ch	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth rate		C/L (No.)	CP (%)	PR (%)	DCP (%)	CW (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop	
					4 th instar	5 th instar										(No)	(g)
C	8.961	31.059	3.894	9.265	0.143	0.086	179.467	88.533	89.750	1.437	1.664	0.321	19.300	1.274	3.608	8853.330	14774.990
P	8.920	30.941	7.458	8.043	0.141	0.082	177.400	81.656	90.417	1.388	1.619	0.293	18.150	1.256	3.282	8165.560	13249.290
O	9.112	30.613	4.704	13.850	0.140	0.078	191.911	76.689	88.250	0.961	1.506	0.272	18.105	1.164	2.982	7668.890	11549.080
M	10.711	33.725	5.600	17.489	0.137	0.058	205.917	71.333	79.333	1.499	1.372	0.234	17.080	1.069	2.193	6966.670	9553.590
F	5.400**	21.790**	30.520**	73.080**	1.000	71.340**	32.070**	453.410**	10.140**	0.270	268.960**	287.970**	62.810**	189.330**	666.390**	526.220**	1881.380**
LSD 5%	1.053	0.877	0.788	1.445	-	0.004	6.478	0.978	4.508	-	0.022	0.006	0.318	0.019	0.066	98.700	147.2

Where: C, P, O, and M (TRT= Treatments) & CH: Character & (*) significant at 0.05, (**) highly significant at 0.01.

As mentioned in Table 2 differentiation between some different hybrids of the silkworm, *B. mori* L. Significant differences were detected for traits of young larvae mortality, grown larvae mortality, growth rate 4th and 5th instar, cocoons number/litter, pupation percentage, weights of cocoon, shell, and pupa, cocoon shell %, productivity of silk, number and weight of cocoon output. Hybrids Hy G, and Hy K gained better results for most investigation traits. The performance of foundation crosses varies seasonally due to the different origins of the parental strains involved.

Table 2. Differentiations between different hybrids of silkworm *B. mori* L.

Character Treatment	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth Rate		C/L (No.)	CP (%)	PR (%)	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop	
					4 th instar	5 th instar										(No)	(g)
Hy C	9.3354	31.476	4.3498	13.0183	0.140	0.078	183.196	80.450	87.625	1.0811	1.546	0.278	17.999	1.197	3.020	7920.00	12334.17
Hy K	9.4487	31.576	6.3266	10.4000	0.150	0.079	186.325	83.183	88.938	1.8018	1.596	0.301	18.878	1.226	3.239	8318.33	13360.61
Hy H	9.497	31.700	5.5661	13.0668	0.136	0.071	196.500	75.025	84.250	1.0808	1.479	0.260	17.600	1.149	2.799	7502.50	11150.43
F Between hybrids	0.070	0.180	17.270**	12.030**	4.670**	12.960**	11.940**	194.440**	2.980**	1.050	72.820**	118.240**	42.400**	43.510**	113.010**	184.070**	608.370**
LSD 5%	-	-	0.682	1.251	0.006	0.004	5.610	0.847	3.904	-	0.019	0.005	0.275	0.017	0.056	85.500	127.500

Where: (*) significant at 0.05, (**) highly significant at 0.01.

Table 3 shows obvious differentiations between young and whole instars of silkworm *B. mori* L. Significant differences were noted between the growth rate of 4th, cocoon number/litter, cocooning percentage, cocoon weight, cocoon shell weight, pupa weight, silk productivity, and cocoon production by number and weight. Using treatment envelop1 with plastic during whole instars was better than usage during young instar only. This is may be due to the plastic keeping the temperatures degrees and humidity percentages with the ambit good of silkworm rearing. Also, conserving the mulberry leaves freshness makes leaves available for the longest possible period, fresh, and thus the larvae feed more, which is reflected in the health of the larvae and their resistance. These data are agreed with the data of (Natarikar *et al.* 2023 & Ogli and Maxmatqobilovna 2023) suggested that abiotic factors will directly affect physiological activities of silkworm larvae, the use of cloth and polyethylene film in the young silkworm rearing reduced the larval period to 3-4 days, saved the leaf consumption to 15-19%, and mellowness of mulberry remains up, getting less dried whereas lead to grow the maximum cocoon yield.

Table 3. Differentiations between young and whole instars of silkworm *B. mori* L.

Character Treatment	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth rate		C/L (No.)	CP (%)	PR (%)	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop	
					4 th instar	5 th instar										(No)	(g)
Young instars	9.560	31.394	5.5819	11.825	0.119	0.075	191.567	78.333	85.917	0.939	1.511	0.274	18.140	1.167	2.929	7833.330	11893.290
Whole Instars	9.2916	31.775	5.2465	12.498	0.162	0.078	185.781	80.772	87.958	1.704	1.569	0.285	18.1769	1.214	3.104	7993.890	12670.190
F Between instar	0.530	1.520	1.470	1.760	321.100**	2.570	6.200*	50.310**	1.590	2.660	53.660**	28.540**	0.100	46.280**	55.810**	21.380**	225.130**
LSD 5%	-	-	-	-	0.005	-	4.581	0.691	-	-	0.016	0.004	-	0.014	0.046	69.81	104.100

Where: (*) significant at 0.05, (**) highly significant at 0.01.

Data in Table 4 showed the differentiation between interactions of some silkworms, *B. mori*, rearing techniques, treatments, young and whole instars. There were significant differences in the interactions between treatments and instars of most traits under study. Generally, the traits of the silkworm were enhanced in treatments of enveloped type 1 and type 2. Best results were detected for treatments in whole instars. these proved that polyethylene envelopes work to maintain the climatic conditions of temperature and humidity, which works to improve the growth quality of silkworm larvae. These results confirm those found by Kumar *et al.* (2022) recorded that the whole larval duration was reduced to 37 days at a temperature 25°C, whilst recording 40 days at the room temperature with 75% relative humidity.

Data in Table 5 showed the differentiation between interactions of some silkworm, *B. mori*, rearing techniques treatments, and silkworm hybrids. Treatments C and P were better than N and M treatments. The hybrids Hy G and Hy K were the better hybrids to the previous treatments. The preceding findings are conformity with the results found by Hussein *et al.* (2011a) evaluated six lines of silkworm at 25°C in incorporation with various

relative humidity and the highest fecundity, hatchability, pupation ratio, and low mortality percentage was observed at 80% RH. In addition, (Hosamani *et al.* 2022 & Fouad and Gad, 2023) they evaluated season fluctuations, environmental conditions, and different local silkworm hybrids in different locations. Season fluctuation and environmental conditions have a significant effect on the quality of silkworm crops. The performance of the same hybrid varied according to each location's environmental factors.

Table 4. Differentiation between interactions of silkworm, *B. mori*, rearing techniques treatments and young and whole instars.

Character	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth Rate		CP (%)	PR (%)	DCP (%)	C/L (No.)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop		
					4th instar	5th instar										(No)	(g)	
Treatment																		
C	Y	8.766	31.089	6.277	7.022	0.122	0.086	84.600	90.667	1.096	181.100	1.606	0.302	18.851	1.232	3.462	8460.000	13598.679
	W	9.167	31.028	1.511	11.508	0.164	0.086	92.467	88.833	1.778	177.833	1.724	0.339	19.749	1.316	3.763	9246.667	15951.309
P	Y	8.839	30.839	5.461	8.067	0.121	0.082	79.267	90.167	0.923	179.533	1.592	0.291	18.341	1.231	3.290	7926.667	12641.883
	W	9.000	31.042	9.455	8.019	0.162	0.083	84.044	90.667	1.852	175.267	1.646	0.295	17.960	1.281	3.275	8404.444	13856.693
O	Y	9.225	30.225	5.533	14.389	0.119	0.076	77.067	89.167	1.071	197.600	1.528	0.275	18.089	1.183	2.987	7706.667	11768.287
	W	9.000	31.000	3.875	13.311	0.161	0.079	76.311	87.333	0.852	197.600	1.483	0.268	18.121	1.145	2.978	7631.111	11329.880
M	Y	11.422	33.422	5.056	17.822	0.114	0.056	72.400	73.667	0.665	208.033	1.320	0.227	17.281	1.023	1.986	7240.000	9564.305
	W	10.000	34.028	6.144	17.156	0.161	0.060	70.267	85.000	2.333	203.800	1.424	0.240	16.878	1.114	2.400	6693.333	9542.969
F (treatment X Instar)	1.200	0.380	45.770**	6.430**	0.300	0.270	46.540**	3.780*	0.690	0.650	21.820**	18.450**	7.050**	18.450**	22.090**	72.480**	148.850**	
LSD 5%	-	-	3.914	4.738	-	-	4.394	7.831	-	-	0.046	0.011	0.524	0.039	0.145	470.860	1056.900	

Where: C, P, O, and M (Treatments) & Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant at 0.01.

Table 5. Differentiation between interactions of some silkworm, *B. mori*, rearing techniques, treatments, and silkworm hybrids.

Character Treatment		FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth Rate		C/L (No.)	CP (%)	PR (%)	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop	
						4th instar	5th instar										(No)	(g)
C	Hy G	8.834	30.855	4.916	9.304	0.142	0.087	173.200	90.400	90.500	1.327	1.651	0.310	18.844	1.271	3.506	9040.000	14950.614
	Hy K	8.917	30.917	3.100	9.333	0.147	0.088	176.000	92.900	91.250	1.721	1.721	0.355	20.701	1.297	3.973	9290.000	16003.125
	Hy H	9.134	31.405	3.667	9.158	0.139	0.083	189.200	82.300	87.500	0.883	1.621	0.297	18.355	1.254	3.344	8230.000	13371.242
	Hy G	8.834	30.855	2.267	8.469	0.141	0.086	172.100	84.900	90.750	1.388	1.614	0.291	18.105	1.253	3.298	8490.000	13704.864
P	Hy K	8.937	30.959	13.750	4.650	0.146	0.087	174.400	87.333	91.500	1.999	1.675	0.311	18.665	1.293	3.483	8733.333	14637.449
	Hy H	8.988	31.009	6.359	11.010	0.137	0.074	185.700	72.733	89.000	0.776	1.567	0.276	17.690	1.222	3.066	7273.333	11405.552
	Hy G	9.000	30.500	3.100	15.867	0.140	0.081	186.233	75.800	87.750	0.277	1.529	0.270	17.608	1.190	2.995	7580.000	11581.552
	Hy K	9.137	30.638	5.857	13.317	0.145	0.082	193.600	79.100	90.000	1.665	1.529	0.282	18.569	1.177	3.091	7910.000	12092.582
O	Hy H	9.200	30.700	5.156	12.367	0.135	0.070	195.900	75.167	87.000	0.943	1.459	0.263	18.137	1.126	2.860	7516.667	10973.117
	Hy G	10.675	33.696	7.117	18.433	0.136	0.058	201.250	70.700	81.500	1.333	1.388	0.242	17.437	1.076	2.280	6570.000	9099.657
	Hy K	10.792	33.792	2.600	14.390	0.142	0.061	201.300	73.400	83.000	1.443	1.460	0.254	17.576	1.136	2.374	7340.000	10709.298
	Hy H	10.667	33.688	7.083	19.733	0.134	0.056	215.200	69.900	73.500	1.721	1.269	0.205	16.227	0.994	1.925	6990.000	8851.806
F (treatment X Hybrid)		1.200	0.070	57.280**	5.280**	0.020**	1.230	0.460	28.880**	0.460	0.290	4.710**	8.200**	7.190**	4.500**	6.790**	41.140**	39.780**
LSD 5%		-	-	3.946	3.796	0.014	-	-	2.784	6.283	-	0.049	0.011	0.606	0.044	0.121	317.520	491.270

Where: C, P, O, M (Treatments) & (*) significant at 0.05, (**) highly significant at 0.01.

The Differentiation between interactions of some silkworms, *B. mori* rearing techniques, silkworm hybrids, and silkworm instars were registered in Table 6. There were highly significant variations for young and grown larval mortality, growth rate 4th instar, numbers of cocoons/litter, cocooning percentage, cocoon weight, cocoon shell weight, cocoon shell percentage, pupae weight, the productivity of silk, yield cocoons by number and weigh. The improvement in traits under enveloped treatments 1 and 2 because of providing humidity and temperature that silkworm larvae require to form good cocoons, as humidity increases the amount of time the leaves remain fresh and tender, which increases feeding periods, and the appropriate temperature increases the larvae's metabolism, which is reflected in the quality of the cocoon crop. The obtained results agree with found by (Rahmathulla *et al.* 2012) reported that humidity may affect the quality of mulberry in different instars, silkworm larvae take water only from leaf. Highly nutritious leaves result in sturdy larvae that increase resistance to adverse effects and disease conditions, so keeping the freshness of the leaf is essential for healthy larvae to get good cocoon output.

Differentiation between interactions of some silkworm, *B. mori* rearing techniques treatments, and sexes were found in Table 7. Treatments of C, and P enhancement for the traits of cocoon weight, cocoon shell weight, cocoon shell ratio, pupa weight, and silk

productivity for both sexes. These results were coincidence with the data of Akinwande, (2022) who recorded that fluctuations in the temperature degrees affect the silkworm breeding.

Table 6. Differentiation between interactions of some silkworm, *B. mori* rearing techniques, silkworm hybrids and silkworm instars.

Character		Treatment	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth rate		C/L (No.)	CP (%)	PR (%)	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop	
							4th instar	5th instar										(No)	(g)
C	Hy G	Y	8.667	30.667	8.499	2.733	0.120	0.086	182.400	85.600	91.000	0.653	1.597	0.299	18.7535	1.227	3.453	8560.000	13667.163
		W	9.000	31.042	1.333	15.875	0.164	0.087	164.000	95.200	90.000	2.000	1.705	0.320	18.935	1.315	3.559	9520.000	16234.075
	Hy K	Y	8.833	30.833	4.600	10.333	0.129	0.087	179.200	89.600	92.000	2.533	1.678	0.320	19.1757	1.288	3.618	8960.000	15030.221
		W	9.000	31.000	1.600	8.333	0.166	0.088	172.800	96.200	90.500	1.667	1.765	0.390	22.225	1.305	4.329	9620.000	16976.029
	Hy H	Y	8.767	31.767	5.733	8.000	0.117	0.083	181.700	78.600	89.000	0.100	1.539	0.288	18.624	1.181	3.286	7860.000	12098.662
		W	9.500	31.042	1.600	10.315	0.161	0.083	196.700	86.000	86.000	1.667	1.703	0.306	18.085	1.327	3.403	8600.000	14643.822
P	Hy G	Y	8.667	30.667	3.333	8.533	0.119	0.086	181.200	82.200	90.500	0.553	1.612	0.293	18.197	1.249	3.375	8220.000	13248.092
		W	9.000	31.042	1.200	8.405	0.162	0.087	163.000	87.600	91.000	2.222	1.617	0.290	18.013	1.257	3.220	8760.000	13248.092
	Hy K	Y	8.875	30.875	6.667	7.933	0.128	0.088	177.200	85.000	91.000	1.887	1.624	0.305	18.558	1.249	3.436	8500.000	13804.170
		W	9.000	31.042	20.833	6.384	0.165	0.072	171.600	89.667	92.000	2.111	1.726	0.318	18.4726	1.338	3.531	8966.66	15470.728
	Hy H	Y	8.976	30.975	6.384	7.733	0.115	0.076	180.200	70.600	89.000	0.330	1.540	0.275	17.9665	1.196	3.059	7060.000	10873.388
		W	9.000	31.042	6.333	14.286	0.159	0.080	191.200	74.867	89.000	1.222	1.595	0.277	17.393	1.248	3.073	7486.667	11937.715
O	Hy G	Y	9.000	30.000	5.800	10.533	0.118	0.080	188.800	74.400	88.500	0.553	1.594	0.284	17.764	1.240	3.152	7440.000	11856.161
		W	9.000	31.000	0.400	21.200	0.161	0.083	183.667	77.200	87.000	0.000	1.465	0.256	17.452	1.139	2.839	7720.000	11306.944
	Hy K	Y	9.275	30.275	4.933	16.367	0.125	0.080	200.800	79.800	92.000	1.330	1.500	0.281	18.825	1.149	3.027	7980.000	11970.287
		W	9.000	31.000	6.780	10.267	0.164	0.084	187.200	78.400	88.000	2.000	1.558	0.284	18.314	1.204	3.155	7840.000	12214.877
	Hy H	Y	9.400	30.400	5.867	16.267	0.113	0.069	204.000	77.000	87.000	1.330	1.491	0.261	17.677	1.159	2.781	7700.000	11478.413
		W	9.000	31.000	4.445	8.467	0.158	0.072	187.800	73.333	87.000	0.555	1.427	0.265	18.598	1.093	2.939	7333.333	10467.820
M	Hy G	Y	11.349	33.349	1.233	19.867	0.111	0.055	199.100	70.000	78.000	0.000	1.346	0.231	17.200	1.045	2.033	7000.000	9418.500
		W	10.000	34.042	13.000	17.000	0.160	0.060	203.400	71.400	85.000	2.667	1.430	0.253	17.674	1.108	2.526	6140.000	8789.814
	Hy K	Y	11.583	33.583	4.600	13.800	0.120	0.059	201.800	75.000	80.000	0.998	1.421	0.246	17.435	1.105	2.123	7500.000	10659.150
		W	10.000	34.000	0.600	14.800	0.163	0.062	200.800	71.800	86.000	1.889	1.499	0.263	17.717	1.166	2.626	7180.000	10759.445
	Hy H	Y	11.333	33.333	9.333	19.800	0.109	0.054	223.200	72.200	63.000	0.998	1.193	0.204	17.210	0.919	1.802	7220.000	9615.265
		W	10.000	34.042	4.833	19.667	0.158	0.058	207.200	67.600	84.000	2.444	1.345	0.205	15.244	1.070	2.048	6760.000	9088.347
F (treatment X HybridX instar)			0.030	0.100	49.420**	17.110**	0.180	0.040	2.990**	4.120**	0.600	0.360	4.170**	4.490**	10.100**	6.910**	5.820**	3.690**	7.810**
LSD 5%			-	-	3.914	4.738	-	-	11.820	4.394	-	-	0.0674	0.015	0.8355	0.0599	0.162	470.860	1056.900

Where: C, P, O, M (Treatments) & Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant at 0.01.

Table 7. Differentiation between interactions of some silkworm, *B. mori* rearing techniques treatments and sexes.

Character	C.W (g)		C.S.W (g)		C.S.R (%)		P.W (g)		S.P (cg/day)	
Treatment	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
C	1.773	1.556	0.325	0.316	18.329	20.271	1.377	1.170	3.660	3.555
P	1.713	1.525	0.299	0.287	17.474	18.826	1.344	1.168	3.351	3.214
O	1.618	1.394	0.281	0.262	17.397	18.813	1.267	1.062	3.089	2.876
M	1.477	1.267	0.240	0.227	16.226	17.934	1.168	0.970	2.249	2.137
F (Treatment X Sex)	0.940		0.970		1.430		1.050		1.100	
LSD 5%	-		-		-		-		-	

Where: C, P, O, M (Treatments) & (*) significant at 0.05, (**) highly significant at 0.01.

Differentiation between interactions of some silkworm, *B. mori* hybrids, and sexes for cocoon traits (Table 8.. Hybrids of Hy G and Hy K were the best for both sexes. The former results are in agreement with the findings of Sharma *et al.* (2018) found that rearing chawki worms at room temperature extended the young larval duration and moulting period, resulting in increased leaf consumption (up to 3.5 Kg) and smaller worm size compared to optimal temperature conditions. The larval duration was recorded at 28 days, with cocoon weight averaging 2.22 g and yield at 18.75 Kg. Neelaboina *et al.* (2020) examined eleven bivoltine silkworm breeds, finding that five strains excelled in all seasons.

Table 8. Differentiation between interactions of some silkworm, *B. mori*, hybrids and sexes for cocoon traits.

Character Hybrid	C.W (g)		C.S.W (g)		C.S.R (%)		P.W (g)		S.P (cg/day)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Hy G	1.653	1.438	0.288	0.268	17.417	18.580	1.295	1.0995	3.120	2.911
Hy K	1.708	1.485	0.305	0.297	17.809	19.947	1.333	1.118	3.272	3.189
Hy H	1.575	1.384	0.266	0.254	16.843	18.356	1.239	1.0595	2.86	2.736
F (Hybrid X Sex)	1.510		2.600		6.210**		2.290		2.830	
LSD 5%	-		-		0.430		-		-	

Where: C, P, O, M (Treatments) & (*) significant at 0.05, (**) highly significant at 0.01.

Results in Table 9. Presented the differentiation between instars of the silkworm, *B. mori*, and between interactions of instars and sexes for cocoon traits. Significant differences were noted for cocoon & pupa weight, cocoon shell ratio. Results revealed that whole instars acquired better data than young instars for weight of cocoon, weight of cocoon shell, cocoon shell ratio, pupae weight, and silk productivity for both sexes. They could be agreeing with the suggestion of Islam and Rahman (2018) proved that, the rise in temperature and humidity significantly reduced the larval duration, the reproductive biology of the silkworm was negatively impacted by rise in temperatures and relative humidity.

Table 9. Differentiation between instars of silkworm, *B. mori* and between interactions of instars and sexes for cocoon traits.

Character Treatment	C.W (g)		C.S.W (g)		C.S.R (%)		P.W (g)		S.P (cg/day)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Young Instars	1.594	1.428	0.279	0.268	17.475	18.806	1.245	1.090	2.983	2.874
Whole Instars	1.697	1.442	0.293	0.277	17.238	19.116	1.333	1.095	3.192	3.016
Mean	1.511	1.569	0.274	0.285	18.140	18.177	1.167	1.214	2.929	3.104
F (Instar X Sex)	31.390**		1.500		5.690*		37.210**		2.020	
LSD 5%	0.030		-		0.361		0.024		0.106	

Where: C, P, O, M (Treatments) & (*) significant at 0.05, (**) highly significant at 0.01.

Differentiation between interactions of treatments, instars, and sexes of the silkworm, *B. mori* for cocoon traits (Table 10). There were highly significant differences in interactions between treatments X Instars X sexes for cocoon weight and pupal weight. Treatments C and P (Envelope 1 and 2) were the best for whole instars, followed by N treatment, whereas the ordinary treatment was the worst. These data were coincidental with data of Ramaprasada *et al.* (2004) & Fathy *et al.* (2016) who proved that using plastic sheets enhanced the weight of larva, cocoon, shell, and cocoon shell ratio, than the paraffin paper. These results explained the reason enhancement of these characters may be due to the availability of suitable conditions for growth and development, especially temperatures and humidity as tabulated in Figs 1,2,3,4 in the young instars and Figs 5,6,7, and 8 in whole instars. Hussain *et al.* (2011b) studied the economic cocoon characteristics of eleven silkworm strains at various temperatures and humidity levels and the results indicated that the silkworm lines

thrived better at 25 °C with 70-80% humidity.

Table 10. Differentiation between interactions of treatments, instars and sexes of silkworm, *B. mori*, for cocoon traits.

Character Treatment		CW (g)		CSW (g)		CSR (%)		P W (g)		SP (cg/day)	
		Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
C	Y	1.670	1.539	0.305	0.300	18.205	19.497	1.295	1.170	3.482	3.423
	W	1.876	1.573	0.346	0.332	18.452	21.045	1.460	1.171	3.839	3.688
P	Y	1.658	1.526	0.293	0.288	17.699	18.983	1.295	1.167	3.316	3.2639
	W	1.768	1.523	0.305	0.285	17.249	18.670	1.393	1.169	3.386	3.163
N	Y	1.617	1.439	0.284	0.267	17.565	18.612	1.263	1.102	3.080	2.894
	W	1.619	1.348	0.279	0.257	17.228	19.014	1.270	1.021	3.098	2.858
M	Y	1.430	1.210	0.235	0.219	16.429	18.134	1.126	0.921	2.055	1.917
	W	1.525	1.324	0.244	0.236	16.022	17.735	1.210	1.019	2.444	2.356
F (treatment X Instar X Sex)		6.430**		1.190		1.690		7.110**		0.960	
LSD 5%		0.058		-		-		0.047		-	

Where: C, P, O, M (Treatments) & Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant at 0.01.

Table 11 describes the differentiation between sexes and between interactions of treatments, hybrids, and sexes of the silkworm, *B. mori*, and for cocoon traits. Highly significant differences were detected for cocoon weight, cocoon shell weight, cocoon shell ratio, pupae weight, and silk productivity. Significant differences were detected for cocoon & pupae weight for both sexes. The results revealed that the best hybrids were K, followed by G and H for treatments of C, P, O, and M. These data were in accordance with the data of (Ghazy, 2008 & Ubaydullaevich and ugli, 2016) who discovered that raising silkworm larvae in polythene increased the average cocoon character. Hazarika *et al.* (2023) evaluated the performance of six developed heat shock technology hybrids for the first time at farmers; the hybrids performed superior cocoon yield and high fecundity.

Table 11. Differentiation between sexes and between interactions of treatments, hybrids and sexes of silkworm, *B. mori* and for cocoon traits.

Character Treatment		CW (g)		CSW (g)		CSR (%)		P W (g)		SP (cg/day)	
		Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
C	Hy G	1.764	1.538	0.317	0.303	18.018	19.670	1.377	1.165	3.585	3.426
	Hy K	1.827	1.616	0.357	0.353	19.506	21.895	1.400	1.193	3.996	3.950
	Hy H	1.727	1.515	0.302	0.292	17.462	19.248	1.355	1.153	3.400	3.289
P	Hy G	1.724	1.505	0.300	0.282	17.434	18.777	1.353	1.153	3.400	3.196
	Hy K	1.751	1.598	0.315	0.308	18.041	19.289	1.367	1.220	3.521	3.446
	Hy H	1.664	1.470	0.282	0.270	16.947	18.413	1.313	1.131	3.132	2.999
O	Hy G	1.651	1.407	0.284	0.255	17.171	18.045	1.297	1.082	3.158	2.834
	Hy K	1.648	1.410	0.289	0.276	17.552	19.587	1.289	1.065	3.164	3.019
	Hy H	1.555	1.363	0.271	0.255	17.467	18.807	1.214	1.038	2.945	2.775
M	Hy G	1.475	1.301	0.251	0.233	17.045	17.828	1.154	0.998	2.370	2.190
	Hy K	1.606	1.314	0.259	0.250	16.135	19.017	1.277	0.994	2.407	2.341
	Hy H	1.352	1.186	0.210	0.199	15.496	16.958	1.073	0.916	1.970	1.880
Means		1.645	1.435	0.286	0.273	17.356	18.961	1.289	1.092	3.087	2.945
F between Sex		697.640**		38.380**		196.540**		820.210**		36.720**	
LSD 5%		0.016		0.004		0.225		0.014		0.046	
(treatment X hybrid X Sex)		2.530*		0.080		1.440		3.250**		0.090	
LSD 5%		0.058		-		-		0.050		-	

Where: C, P, O, M (Treatments) & Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant at 0.01.

Table 12. Differentiation between interactions of treatments, hybrids and instars and interactions of treatments, hybrids, instars and sexes of silkworm, *B. mori* and for cocoon traits.

Character Treatment			CW (g)		CSW (g)		CSR (%)		P W (g)		SP (cg/day)	
			Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
C	Hy G	Y	1.647	1.546	0.301	0.298	18.279	19.228	1.276	1.179	3.472	3.434
		W	1.882	1.529	0.333	0.308	17.757	20.113	1.479	1.151	3.699	3.418
	HyK	Y	1.760	1.596	0.322	0.317	18.289	20.063	1.368	1.208	3.643	3.593
		W	1.894	1.636	0.392	0.388	20.723	23.728	1.432	1.178	4.350	4.308
	HyH	Y	1.602	1.476	0.292	0.284	18.047	19.202	1.240	1.122	3.331	3.241
		W	1.851	1.554	0.312	0.300	16.877	19.294	1.469	1.184	3.469	3.337
P	Hy G	Y	1.655	1.569	0.294	0.291	17.777	18.618	1.291	1.207	3.391	3.359
		W	1.792	1.441	0.307	0.273	17.091	18.936	1.415	1.098	3.408	3.032
	HyK	Y	1.700	1.548	0.307	0.302	18.140	19.576	1.323	1.176	3.464	3.408
		W	1.803	1.649	0.322	0.314	17.942	19.003	1.410	1.265	3.578	3.483
	HyH	Y	1.620	1.460	0.278	0.272	17.179	18.754	1.273	1.119	3.093	3.024
		W	1.709	1.480	0.286	0.268	16.714	18.072	1.353	1.143	3.172	2.974
O	Hy G	Y	1.642	1.545	0.287	0.280	17.476	18.052	1.285	1.195	3.191	3.114
		W	1.660	1.269	0.281	0.230	16.865	18.038	1.309	0.970	3.124	2.554
	HyK	Y	1.609	1.391	0.291	0.271	18.088	19.561	1.248	1.050	3.137	2.917
		W	1.687	1.430	0.287	0.281	17.016	19.612	1.330	1.079	3.190	3.120
	HyH	Y	1.560	1.382	0.274	0.249	17.131	18.222	1.256	1.062	2.911	2.651
		W	1.510	1.345	0.268	0.261	17.804	19.391	1.172	1.014	2.979	2.899
M	Hy G	Y	1.409	1.282	0.232	0.230	16.467	17.932	1.107	0.982	2.042	2.024
		W	1.541	1.320	0.270	0.235	17.623	17.724	1.201	1.014	2.698	2.354
	HyK	Y	1.590	1.253	0.260	0.232	16.380	18.489	1.260	0.951	2.245	2.000
		W	1.621	1.376	0.257	0.268	15.890	19.545	1.294	1.038	2.570	2.682
	HyH	Y	1.292	1.094	0.213	0.196	16.440	17.980	1.009	0.829	1.877	1.726
		W	1.412	1.277	0.206	0.203	14.553	15.935	1.136	1.004	2.063	2.033
F (treatment X hybrid X Instar X Sex)			2.920**		0.980		1.440		3.230**		0.800	
LSD 5%			0.076		-		-		0.066		-	

Where: C, P, O, M (Treatments) & Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant at 0.01.

Data in Table 12. obvious the differentiation between interactions of treatments, hybrids, and instars and interactions of treatments, hybrids, instars, and sexes of the silkworm, *B. mori*, and for cocoon traits. There were highly significant differences in interactions through treatments X Hybrid X Instar X Sex for cocoon weight and pupal weight. Hybrid K was the best followed by G hybrid for treatments C and P during the whole instars for both sexes. These results are in line with (Bindroo and Verma 2014) they reported that polythene is more effective and cost-effective than paraffin wax-coated paper for young silkworm rearing. Polythene sheets can be easily disinfected and reused, while enveloped from all four sides prevents moisture loss from the rearing bed and levels can be increased by 15-20% humidity. Normal growth of larvae is mainly dependent on temperature and humidity as principal factors from the environmental component. Generally, from Figures 1 – 10 and results in Tables 1- 12, it could be concluded that treatments of Enveloped type 1 and Enveloped type 2 were the best treatments whereas safe the best temperature and relative humidity needed for larvae. As well as safe the freshness of mulberry leaves for a long time to be available for feeding the larvae.

CONCLUSION

From the figures of temperature degree and relative humidity, it is confirmed that the treatments of Enveloped type 1 and Enveloped type 2 were the best whereas safe the best temperature and relative humidity needed to larvae. As well as safe the freshness of mulberry leaves for a long time to be available for feeding the larvae. In addition, from the results of the traits tables, it could be concluded that most silkworm traits were enhanced when using the Enveloped type 1 and Enveloped type 2 treatments. Because of the climate conditions in Egypt are unsuitable for rearing silkworms. Thus, it could be recommended to use Enveloped type 1 or Enveloped type 2 to improve the silkworm productivity.

Declarations:

Ethics Approval: Not applicable.

Authors Contributions: TA, and GM: Laboratory experiments, Supervision, Rearing, Writing-Reviewing and Editing. TA, and GM: Conceptualization, Preparation and Methodology.

Competing Interests: The author declares no conflict of interest of any kind.

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