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Modifying Grown Mulberry Silkworm, *Bombyx mori* L., Rearing Techniques to Face Low Humidity in Egypt

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ABSTRACT

Mulberry silkworms produced the most precious material in the world represented in silk, which is used to create fabric, carpets, cosmetics, and the military industry. Silkworm larvae are affected by various components of climate change. Controlling the factors surrounding the silkworm larvae is taken into consideration to ensure the sustainability of the silk output. Temperature degrees and relative 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 a silkworm, *Bombyx mori* L. for enhance rearing techniques, also the same treatments were applied for the young instars of the silkworm larvae. Seventeen traits were taken into consideration. There were fifth larval duration and whole larval duration, larval mortality for young and grown larvae, fourth growth rate and fifth growth rate, cocooning percentage, pupation ratio, double cocooning percentage, and cocoons number per liter. Also, the cocoon, shell, and pupa weight, cocoon shell rate, and silk productivity were recorded for females and males. Cocoon crops by number and weight per 10,000 worms were listed. The results clarified that both treatments, Enveloped type 1 and Enveloped type 2, were the best, whereas save the best temperature and relative humidity needed for larvae. As well as save the freshness of mulberry leaves for a long time to be available for feeding the larvae.

Keywords: Silkworm *Bombyx mori*, climate change, rearing techniques, young and grown instars, economic traits, envelope polyethylene.

1. Introduction

Sericulture is a method that contributes to sustainable development in some countries by transforming cocoons into natural silk. Silk" is a precious fiber renowned as the "Attire of the Heavenly People" and embodies splendor, 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: increased amounts of greenhouse gases like nitrous oxide, carbon dioxide, and methane impact climate change. Climate change poses substantial obstacles to producing excellent silk, contributing to the flourishing of the silk industry (Fatima *et al*. 2022). The use of environmental strategies and modifying resources is, therefore, widespread and has gained attention in strategic planning and decision-making in silk production. Environmental factors are one of the main problems facing silkworm farming in temperate regions such as Egypt, which in turn affects the production of mulberry trees and silk, and overcoming them improves productivity through more sustainable production of mulberries and cocoons. 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. Global warming caused by the greenhouse effect harms ecosystems and creatures, altering habitats and deteriorating the environment. The obstacles facing sericulture in Egypt are season, mulberry cultivation, silkworm diseases, and environmental factors. The climate has an

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unfavorable influence on sericulture, as reported by Bhattarcharjya *et al*. 2020 & Bhat *et al*. 2024. Insects are poikilothermic organisms and are very sensible to environment variations. High-temperature degrees have a major effect on the growth and development of insects, biological traits, reproductive capabilities, and ultraspiracle- 1 mRNA expression, which might be associated with the induction of autophagy (Guo *et al*. 2024). Global warming is expected to cause direct and indirect impacts on sericulture, i.e., decreased production of mulberry and cocoon output, breakages in silk thread through spinning or reeling, increased pest and disease happening, soil acidification and salinization, crop-weed competition, and a change in silkworm rearing schedules (Hariharan *et al*. 2024). Efforts and attempts of silkworm scientists by various research centers lead to the development of the rearing techniques, and all factors affecting silk production to enhance the rearing conditions and raise the cocoon yield. The problems facing the sericulturists, coupled with problems of environmental factors (high temperature and low humidity) and the load of diseases dominant in the temperate region, result in a decline in cocoon yield (Sudan *et al*. 2023). Scientists aim to produce silkworm hybrids that can adapt to climate change. Silkworm larvae are reared at the suitable temperature degrees of 22-26 ºC & 80-85% relative humidity percentages reducing mortality ratio and increasing the pupae weight, but silkworm larvae with un-optimal temperature degrees, cocoon crops per box can decrease by 15-30 kilograms, and quality can be 14% lower (Bekkamov and Samatova, 2023). Also, the rearing of the silkworm, *B. mori* larvae, differs significantly with seasons and locations, whereas, larvae weight, larval survival, cocoon and shell weight, shell portion, filament length, and cocoon output differed (Kumar, 2020 & Kant *et al*. 2024). Fluctuations in temperature degrees are dangerous for physiological silkworms when they surpass 30°C or decrease below 20°C, but silkworm growth requires the optimum temperature of 23 - 28°C for maximum productivity (Gupta and Dubey, 2021). The grown silkworm larvae prefer low temperature to little instars and variations of temperature degrees through various instars of larval development is more preferable of growth and development worms than constant temperature. Because of the lower intake of mulberry leaves during the first and second instars, the activity of enzymes involved in food breakdown decreases, resulting in reduced heat generation in the silkworm body. It is fundamental to save suitable temperature degrees for a successful cocoon output (Torres McCook *et al*. 2021). Factors affecting silkworm rearing are mulberry varieties, good leaves, and environmental conditions (temperature, relative humidity, ventilation, and lighting). The previous elements are the most important abiotic factors that should be controlled to succeed in silkworm rearing. Heat is supposedly the more important factor for cold-blooded animals, they can't adjust body heat during internal mechanisms and relative humidity. Four primary factors affect the raising of *B. mori*: the environment, food, illnesses, and larvae. The lifespan of *B. mori*, cocoon quality, and rearing production are all impacted by slight changes in the surrounding environment. Strict monitoring of these parameters is required in breeding facilities due to their constant variation throughout the seasons. The worms in the fifth instar ingest more than 88 % of mulberry leaves and then develop the silk gland, which occupies up to 40 % of their weight. Therefore, great care must be taken regarding the prevailing temperatures during that period due to the sensitivity of the larvae at this important stage. Superior developmental and growth rates of silkworm larvae raised under the most suitable climatic conditions of 22-26°C and 75-85% relative humidity contribute to increased outcomes of sericulture production. Sinha and Sanyal (2013) state that silkworms were more tolerant of temperatures 17°C & 33°C, whereas 43°C proved deadly. Heat stress increased the number of protein species in larval hemolymph, with 72 kDa kinetics varied with instar. Heat stress enhanced the presence of 95 kDa protein in late instar larval hemolymph, Technological progress has resulted in the achievement of boosting silk quality by managing environmental conditions, as well as effective cocoon accumulation.

Silkworm larvae are cold-blooded organisms whose body temperature is roughly identical to that of their surroundings environment; hence, temperature changes affect insect habits, dispersion, growth, development, survival, and reproduction. The highest temperature during the grown larvae is the most damaging climatic condition that may negatively affect the silkworm and cocoon production. 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 a rearing technique to face the low relative humidity and degrees of temperature during the Spring season to increase cocoon production.

2-Material and Methods

Silkworm resources

Three mulberry silkworm hybrids were imported from Bulgaria and used in this experiment:

- G_2 X K_2 X H_1X KK Coded as G
- KK_1 X K_2 X H_1 X KK Coded as K
- H_1 X KK X V_2 X G_2 Coded as H

Experimental Design:

There are four treatments applied for young instars only, and the same treatments were applied for the whole instars of the silkworm larvae. They are carried out as follows:

I- Treatments through young instar only

1- Enveloped type 1

Silkworms reared using rearing stands enveloped by plastic sheets and larvae reared on plastic sheets coded as (C) treatment.

2- Enveloped type 2

Silkworms reared using rearing stands enveloped by plastic sheets and larvae reared on paraffin paper coded as (P) treatment.

3- Normal silkworm rearing

During the young instars silkworm, the larvae were reared on a polythene sheet and covered with the same plastic sheet. This was coded as (N) treatment.

4- Mixing plastic sheet and paraffin paper

Silkworms were reared with a plastic sheet and coated with paraffin paper coded as (M) treatment. These treatments are applied during the first three instars. During the fourth and fifth instar, regular methods were carried out.

II- Treatments through young instar and grown silkworm (whole instars).

1- Enveloped type 1

Silkworms reared using rearing stands enveloped by plastic sheets and larvae reared on plastic sheet (C).

2- Enveloped type 2

Silkworms were reared using rearing stands enveloped by plastic sheets and larvae reared on paraffin paper (P).

3- Normal silkworm rearing

The larvae were through the young instars silkworm reared on a polythene sheet and covered with the same plastic sheet during the whole instar. This treatment was coded as (N).

4- Mixing plastic sheet and paraffin paper

Silkworm larvae were reared with a plastic sheet, covered with paraffin paper, and coded as (M). The previous rearing methods are conducted during the whole larval duration.

Rearing procedure

The larvae of silkworm were fed a mulberry variety of *Morus alba* var kokuso-27 four times daily. The experiments were carried out at Qanater silk station in Qalubeiya governorate. Chopped mulberry leaves were offered during the young instars. Wit foam strips are used to increase the humidity during young instars and are 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). After maturation, the larvae were put in the collapsible frames for mountage. 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 the rearing room.

The treatments were applied as mentioned in the experimental design

I- Treatments through young instar only

After the third moult, the plastic envelope and coverage were removed, and the larvae were reared under the rearing room temperature and humidity.

II- Treatments through young and grown instar silkworms (whole instars)

After the third moult, the plastic envelope and coverage were continuous till the mountage started.

Silkworm characteristics

The collected data are registered for all the treatments of seventeen characters viz., fifth (5^{th} LD) and whole larval duration (WLD), larval mortality for young (YLM) and grown larvae (GLM), fourth growth rate (4^{th} GR) and fifth growth rate (5^{th} GR), cocooning percentage (CP), pupation ratio (PR), double cocooning % (DCP), cocoon numbers per liter (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 Wald Bauer (1968) as follows:

$$\textbf{Growth rate} = \frac{W_2 - W_1}{W_1}$$

Where:
W_1: Initial weight of the larvae (g)
W_2: Final weight of the larvae (g)
The pupation % was registered according to the following formula by Lea (1996):

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

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

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

Where cg: Centigram

Statistical analysis

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

3. Results and Discussion

Data appearing in figure 1 showed 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 explained that both room temperature and relative humidity were recorded lowest values for minimum, maximum, and average compared with all treatments. It could be concluded that the treatments enhanced the temperatures and relative humidity.

Figures 2-5 illustrate the registered temperature and relative humidity of each treatment during the young instar for the rearing cycle. Results discerned that those treatments of C and P recorded near optimum temperature degrees and relative humidity percentages, whereas treatments of N and M registered the lowest temperature degrees and relative humidity percentages. So, treatments of C and P may be improving the characters of the silkworm, *B. mori*, because they enhance the climatic conditions. It also keeps the freshness of mulberry leaves for a longer time, making them available for feeding the silkworm larvae.

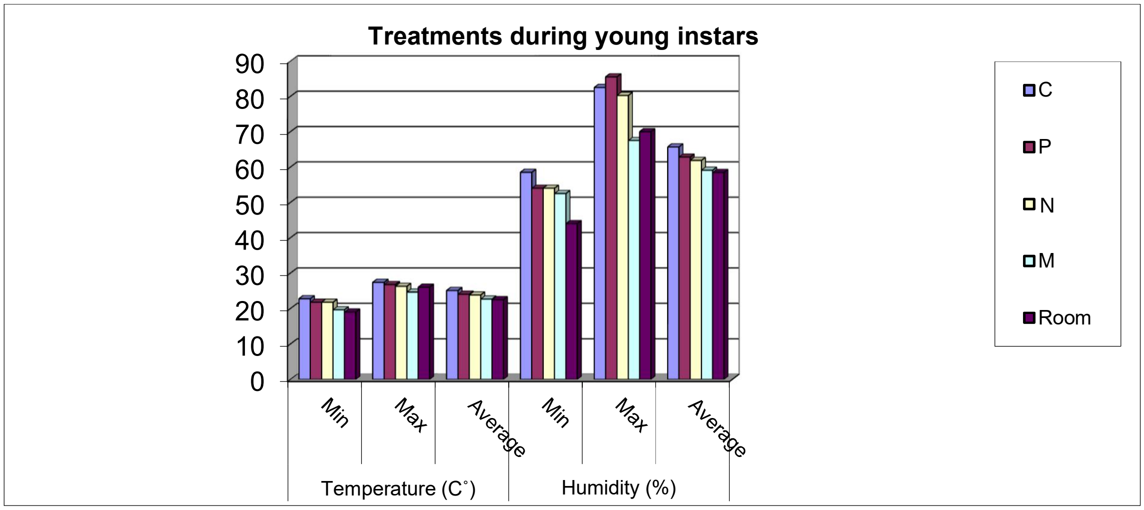

Fig. 1: Minimum, maximum, and average of temperature degrees and relative humidity percentages.

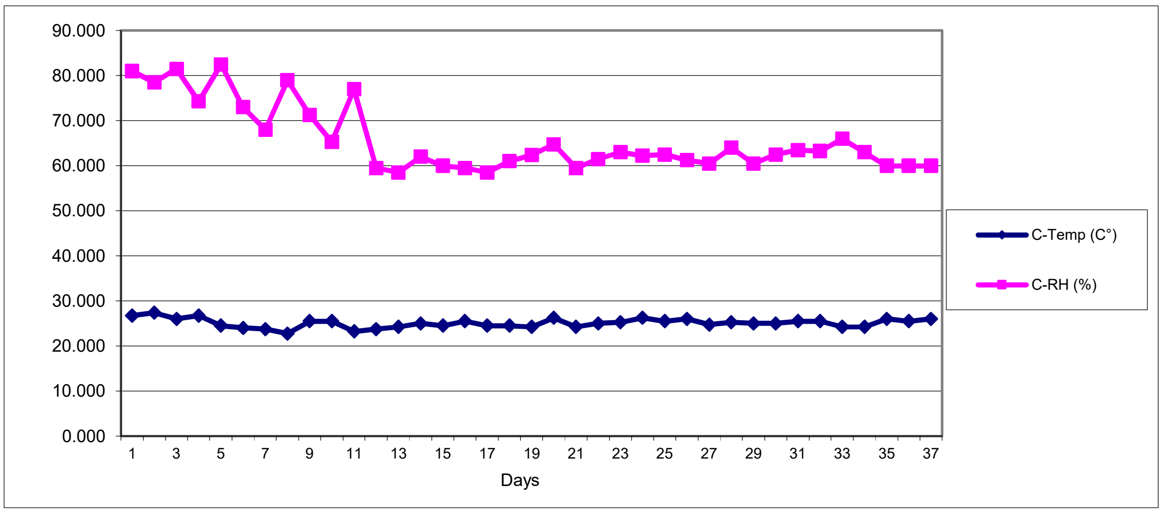

Fig. 2: Temperature degrees and relative humidity inside the C treatment during the young instars.

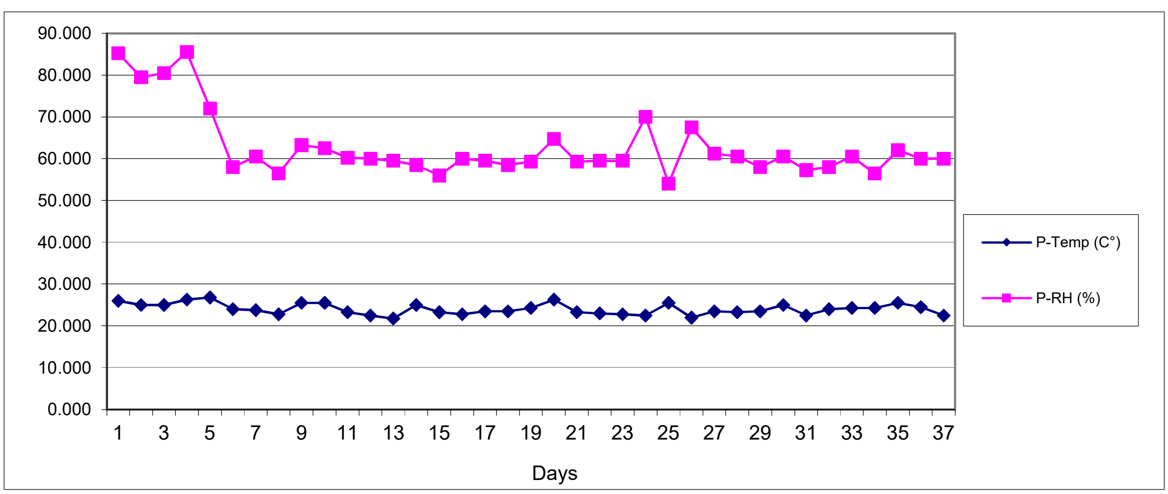

Fig. 3: Temperature degrees and relative humidity inside the P treatment during the young instars.

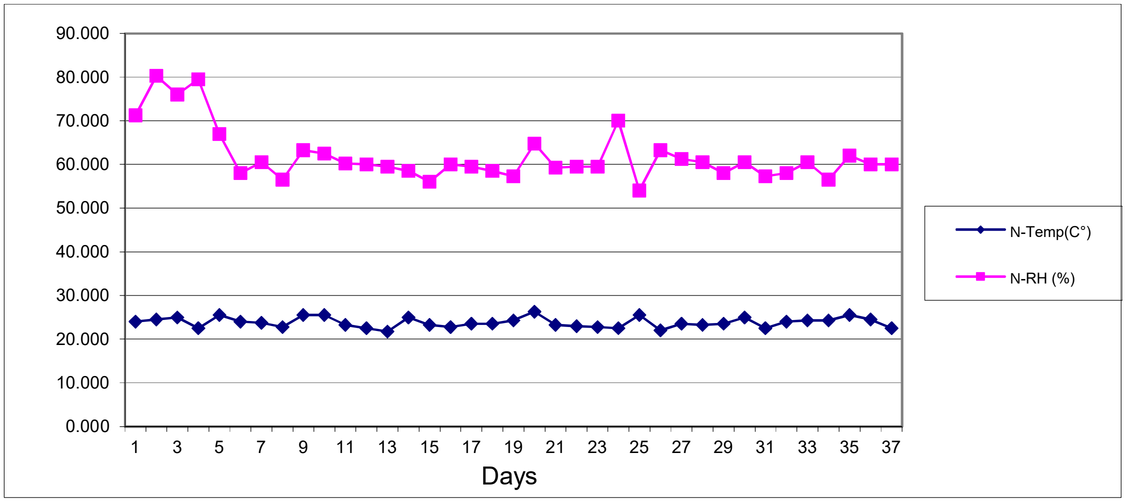

Fig.4: Temperature degrees and relative humidity inside the N treatment during the young instars.

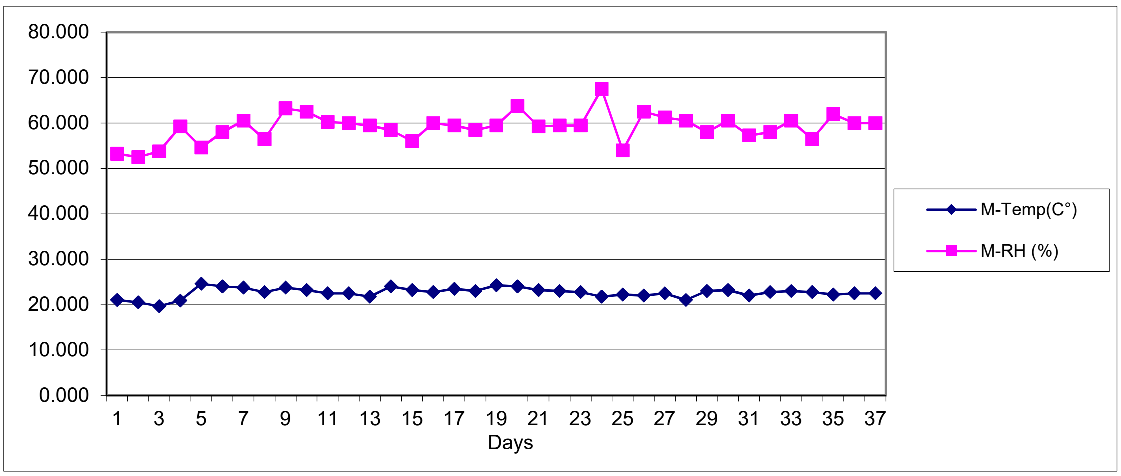

Fig.5: Temperature degrees and relative humidity inside the M treatment during the young instars.

Figure 6 revealed the minimum, maximum, and mean temperature degrees & relative humidity percentages for treatments through whole instars. It 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 for the silkworm, *B. mori.* These may be led to improve the traits of the mulberry silkworm.

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. On the contrary, treatments of N and M have the lowest degrees of temperature and relative humidity percentages.

These results are coincidental with the data of Krishnaswami (1990), who 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% to 90%. The grown silkworm ranged from 23-25 ˚C and 70-75%. The amount of water is constant from the second to the fourth instar. The fifth instar after molting has the highest water content, which gradually decreases as the worm gets older. Younger silkworms (first instar) take up more water from mulberry leaves than older silkworms (fifth instar), whose water content is lower than that of the leaves. The humidity needed by young worms is greater (80–90%) and decreases by 50% with each instar. Older worms may live in 60–70% humidity, depending on the breed, environment, and food. The breed, developmental stage, and environment of the silkworm should all be taken into consideration while adjusting the temperature and humidity levels.

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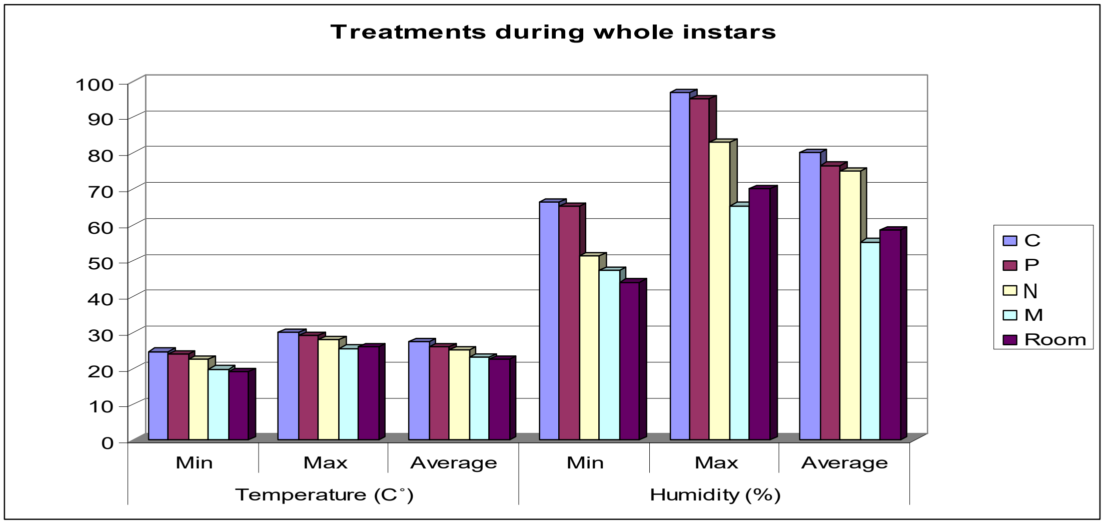

Fig. 6: Minimum, maximum, and average of temperature degrees and relative humidity percentage

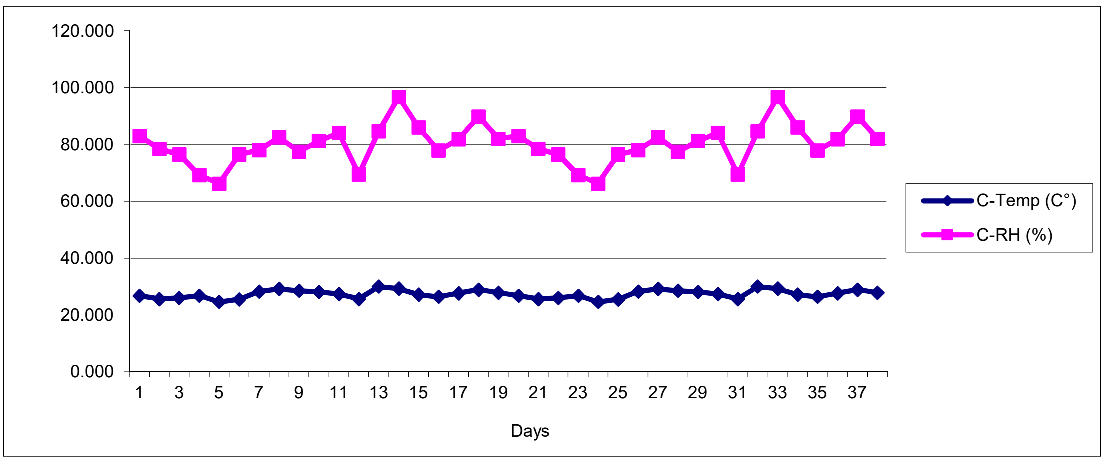

Fig.7: Temperature degrees and relative humidity inside the C treatment during the whole instars

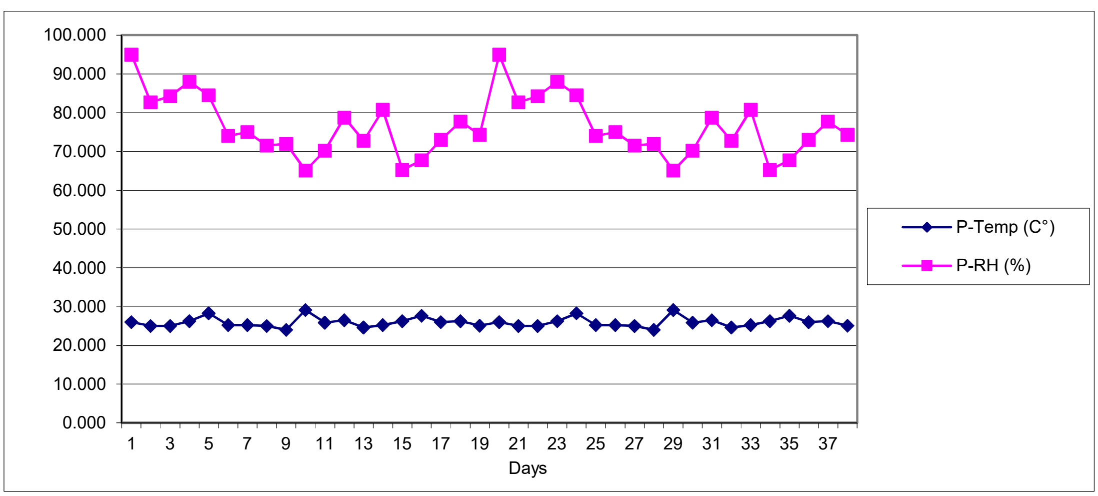

Fig. 8: Temperature degrees and relative humidity inside the P during the Whole instars

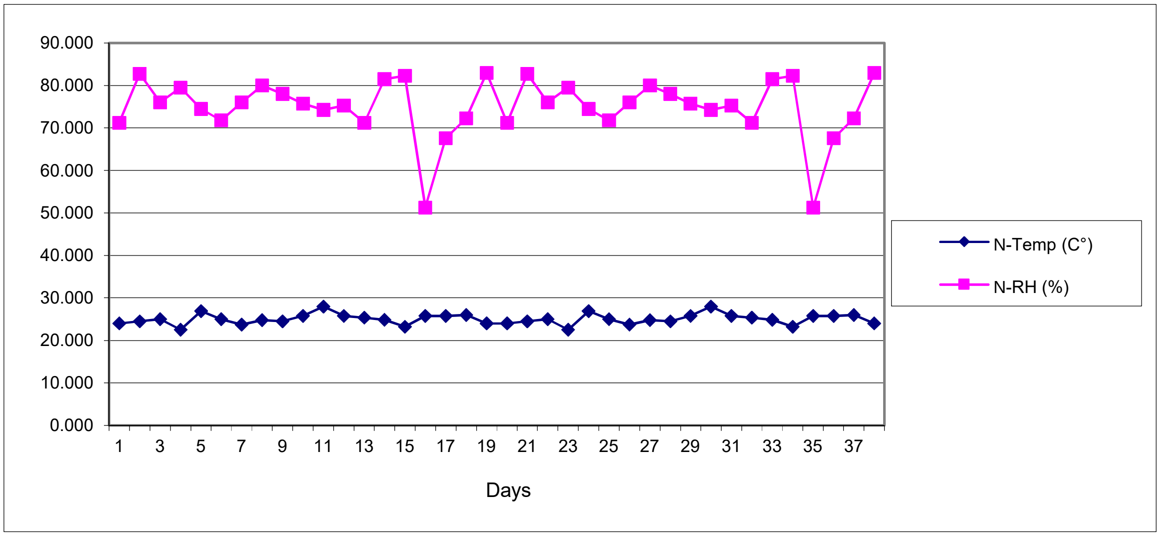

Fig. 9: Temperature degrees and relative humidity inside the N treatment during the whole instars

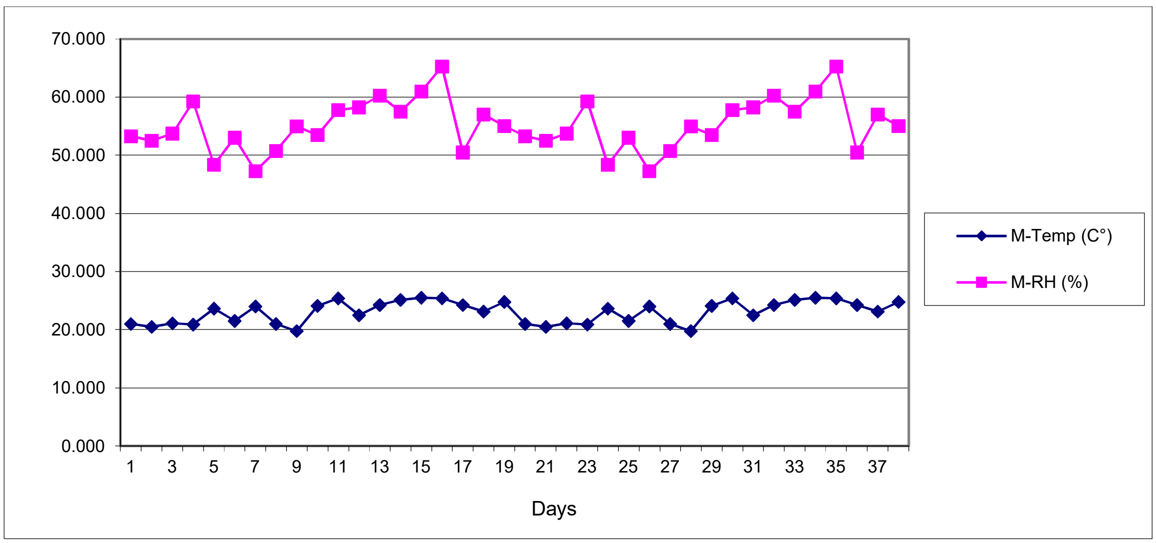

Fig. 10: Temperature degrees and relative humidity inside the M treatment during the whole instars

Differentiation between some rearing silkworm techniques treatments in Table 1 data revealed highly significant differences between treatments for all traits except double cocoon percentage. Treatments of enveloped type 1 (C) and enveloped type 2 (P) have better means values for most characters under study. Using treatments of C and P is the best treatment under experiment enhancing the silkworm characters, these results agree that maybe the enveloped trays with plastic sheets save temperature degrees, and humidity percentages with the range be suitable for the survival and development of silkworm larvae. These findings are consistent with those observed by Datta *et al*. (2013) reported that chawki rearing practices using box and wrap-up methods resulted in much superior to open type of shelf rearing by Providing optimal microclimatic conditions (temperature and humidity) for larval growth and development leads to improved economic performance. Also, Sudan *et al*. (2020) used polythene sheets for silkworm rearing to evaluate the moisture content and moisture retention capacity for five mulberry varieties through young and late ages to maintain suitable temperature degrees and relative humidity.

In addition, Rahmathulla *et al* (2012)reared the late instar bivoltine strain of silkworm under different nutritional and environmental stress conditions. The parameters of economic and nutritional characters were significantly raised when reared at ideal temperature and humidity conditions and fed on mulberry leaf with sufficient leaf moisture. Humidity is critical for silkworm growth and has a direct impact on their physiological functioning. Optimal humidity percentage helps to ideal silkworm growth, development, and high-quality cocoon output. Young instars (1st, 2nd, and 3rd) can withstand greater humidity levels than grown silkworms, which results in rapid development. Maintaining humidity at roughly 90% throughout the early instars, paired with a temperature of 26-28°C, provides for healthy growth without substantial harmful consequences.

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

Ch / TRT	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth rate 4th instar	Growth rate 5th instar	C/L (No.)	CP (%)	PR (%)
C	8.961	31.059	3.894	9.265	0.143	0.086	179.467	88.533	89.750
P	8.920	30.941	7.458	8.043	0.141	0.082	177.400	81.656	90.417
N	9.112	30.613	4.704	13.850	0.140	0.078	191.911	76.689	88.250
M	10.711	33.725	5.600	17.489	0.137	0.058	205.917	71.333	79.333
F Between treatments	5.400**	21.790**	30.520**	73.080**	1.000	71.340**	32.070**	453.410**	10.140**
LSD 5%	**1.053**	**0.877**	**0.788**	**1.445**	**-**	**0.004**	**6.478**	**0.978**	**4.508**

Table 1: Cont.

Ch / TRT	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop (No)	Cocoon Crop (g)
C	1.437	1.664	0.321	19.300	1.274	3.608	8853.330	14774.990
P	1.388	1.619	0.293	18.150	1.256	3.282	8165.560	13249.290
N	0.961	1.506	0.272	18.105	1.164	2.982	7668.890	11549.080
M	1.499	1.372	0.234	17.080	1.069	2.193	6966.670	9553.590
F Between treatments	0.270	268.960**	287.970**	62.810**	189.330**	666.390**	526.220**	1881.380**
LSD 5%	**-**	**0.022**	**0.006**	**0.318**	**0.019**	**0.066**	**98.700**	**147.2**

Where: C, P, N, 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/liter, pupation percentage, (cocoon, shell, and pupa weight), cocoon shell %, productivity of silk, number and weight of cocoon output. There were insignificant differences for fifth duration, whole larval period, and double cocooning % characters. Hybrids Hy G and Hy K gained better results for most investigated traits. These findings are consistent with those of Neelaboina *et al*. (2019), who evaluated the performance of 24 foundation crosses in all three seasons under temperate climatic conditions. The performance of foundation crosses varies seasonally due to the different origins of the parental strains involved. Three constricted foundation crosses (SK-6 × SK-7, Pam-117 × APS-4, and Pam-117 × SK-7) and four oval foundation crosses (CSR-27 × Pam-114, CSR-50 × Pam-114, Pam-114 × CSR-27, and Pam-114 ×CSR-50) were found suitable for temperate regions. Also, Fouad (2020) noted that the performances of silkworm hybrid traits are changed according to environmental factors, and the regional variations in ecological constitutes extremely affect the genotypic expression.

Table 3 showed obvious differentiations between young and whole instars of silkworm *B. mori* L. Significant differences were noted between growth rate of 4th, cocoon number/liter, cocooning percentage, cocoon weight, cocoon shell weight, pupa weight, silk productivity, and cocoon production by number and weight. On the other hand, there were insignificant differences for the 5th duration, whole larval duration, young and grown larval mortality, growth rate 5th instar, pupation ratio, double cocoon percentage, and cocoon shell ratio traits.

Using treatment envelope 1 with plastic during the whole instars was better than usage during young instar only. This 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 Ogli and

Maxmatqobilovna (2023) resulted that, 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 2: Differentiations between different hybrids of silkworm *B. mori* L.

Character / Treatment	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth Rate 4th instar	Growth Rate 5th instar	C/L (No.)	CP (%)	PR (%)
Hy G	9.3354	31.476	4.3498	13.0183	0.140	0.078	183.196	80.450	87.625
Hy K	9.4457	31.576	6.3266	10.4000	0.150	0.079	186.325	83.183	88.938
Hy H	9.497	31.700	5.5661	13.0668	0.136	0.071	196.500	75.025	84.250
F Between hybrids	0.070	0.180	17.270**	12.030**	4.670**	12.960**	11.940**	194.440**	2.980**
LSD 5%	-	-	**0.682**	**1.251**	**0.006**	**0.004**	**5.610**	**0.847**	**3.904**

Table 2: Cont.

Character / Treatment	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop (No)	Cocoon Crop (g)
Hy G	1.0811	1.546	0.278	17.999	1.197	3.020	7920.00	12334.17
Hy K	1.8018	1.596	0.301	18.878	1.226	3.239	8318.33	13360.61
Hy H	1.0808	1.479	0.260	17.600	1.149	2.799	7502.50	11150.43
F Between hybrids	1.050	72.820**	118.240**	42.400**	43.510**	113.010**	184.070**	608.370**
LSD 5%	-	**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: Differentiations between young and whole instars of silkworm *B. mori* L.

Character / Treatment	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth rate 4th instar	Growth rate 5th instar	C/L (No.)	CP (%)	PR (%)
Young instars	9.560	31.394	5.5819	11.825	0.119	0.075	191.567	78.333	85.917
Whole Instars	9.2916	31.775	5.2465	12.498	0.162	0.078	185.781	80.772	87.958
F Between instar	0.530	1.520	1.470	1.760	321.100**	2.570	6.200*	50.310**	1.590
LSD 5%	-	-	-	-	**0.005**	-	**4.581**	**0.691**	-

Table 3: Cont.

Character / Treatment	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop (No)	Cocoon Crop (g)
Young instars	0.939	1.511	0.274	18.140	1.167	2.929	7833.330	11893.290
Whole Instars	1.704	1.569	0.285	18.1769	1.214	3.104	7993.890	12670.190
F Between instar	2.660	53.660**	28.540**	0.100	46.280**	55.810**	21.380**	225.130**
LSD 5%	-	**0.016**	**0.004**	-	**0.014**	**0.046**	**69.81**	**104.100**

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

This is due to the availability of suitable conditions for growth, including temperature and relative humidity. Also, Natikar *et al*. (2023) suggested that abiotic factors will directly affect the physiological activities of silkworm larvae because silkworms are cold-blooded, whereas the temperature degrees play a vital role in the survival and outcome of silkworm, *B. mori* L., ideal temperature is 22-27°C.

Cocoons quality is also impacted by environmental factors, the young instar larvae prefer high temperatures which also support enhance effective rate of rearing and cocoon characteristics. Contrariwise, high temperatures through silkworm rearing, especially at grown instars, hasten larvae growth and shorten the larvae duration. Otherwise, the low degrees of temperature postpone the development of larvae and increase the larval duration.

Data in Table 4 showed the differentiation between interactions of some silkworms, *B. mori* rearing techniques treatments, and young and whole instars. There were significant differences in the interactions between treatments and instars of all traits under study except traits of fifth duration, whole

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larval duration, growth rate of 5th instar, double cocooning percentage, and cocoons number for each liter. Generally, the traits of the silkworm were enhanced in treatments of enveloped type 1 and type 2. The best results were detected for treatments in whole instars. This proved that polyethylene enveloped works 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), who recorded that the whole larval duration was reduced to 37 days at the temperature 25±1°C whilst recording 40 days at the room temperature with 75±5% relative humidity. Also, reduced the larval mortality than the room temperature. In addition, Ramesh *et al*. 2009 reported that temperature and relative humidity are principal environmental agents that impact the insect's physiology and phenotypic expression.

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

Character / Treatment		FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth Rate 4th instar	Growth Rate 5th instar	CP (%)	PR (%)
C	Y	8.756	31.089	6.277	7.022	0.122	0.086	84.600	90.667
	W	9.167	31.028	1.511	11.508	0.164	0.086	92.467	88.833
P	Y	8.839	30.839	5.461	8.067	0.121	0.082	79.267	90.167
	W	9.000	31.042	9.455	8.019	0.162	0.083	84.044	90.667
N	Y	9.225	30.225	5.533	14.389	0.119	0.076	77.067	89.167
	W	9.000	31.000	3.875	13.311	0.161	0.079	76.311	87.333
M	Y	11.422	33.422	5.056	17.822	0.114	0.056	72.400	73.667
	W	10.000	34.028	6.144	17.156	0.161	0.060	70.267	85.000
F (Treatment X Instar)		1.200	0.380	45.770**	6.430**	0.300	0.270	46.540**	3.780*
LSD 5%		-	-	**3.914**	**4.738**	-	-	**4.394**	**7.831**

Table 4: Cont.

Character / Treatment		DCP (%)	C/L (No)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop (No)	Cocoon Crop (g)
C	Y	1.096	181.100	1.605	0.302	18.851	1.232	3.452	8460.000	13598.679
	W	1.778	177.833	1.724	0.339	19.749	1.316	3.763	9246.667	15951.309
P	Y	0.923	179.533	1.592	0.291	18.341	1.231	3.290	7926.667	12641.883
	W	1.852	175.267	1.646	0.295	17.960	1.281	3.275	8404.444	13856.693
N	Y	1.071	197.600	1.528	0.275	18.089	1.183	2.987	7706.667	11768.287
	W	0.852	197.600	1.483	0.268	18.121	1.145	2.978	7631.111	11329.880
M	Y	0.665	208.033	1.320	0.227	17.281	1.023	1.986	7240.000	9564.305
	W	2.333	203.800	1.424	0.240	16.878	1.114	2.400	6693.333	9542.869
F (Treatment X Instar)		0.690	0.650	21.820**	18.450**	7.050**	18.450**	22.090**	72.480**	148.850**
LSD 5%		-	-	**0.046**	**0.011**	**0.524**	**0.039**	**0.145**	**470.860**	**1056.900**

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

Also, Hussain *et al*. (2011a) experimented with eleven silkworm lines at various temperatures and relative humidity conditions (25, 30, and 35 °C) and (55, 65, and 75%) during the grown instars for pupation, hatchability, and larval mortality. The grown larvae instars were exposed to different temperature regimes (25, 30, and 35°C). The Significant differences were noticed with different temperature and humidity treatments on grown instars. Lower (55 - 65% RH) even at 25°C reduced the hatchability percentage and pupation % for silkworm lines and contributed significantly in higher mortality. A temperature of 25-26 °C & humidity of 70–80% are superior to biological silkworm traits.

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 to results found by Hussein *et al*. (2011b), who evaluated six lines of silkworms at 25˚C in incorporation with various relative humidity 50%, 60%, 70%, 80%, and 90% RH. The highest fecundity, hatchability, pupation ratio, and low mortality percentage were observed at 80% RH. superior performance of three silkworm lines was detected for all characters. In addition, Fouad and Gad (2023) evaluated six local silkworm hybrids in two Egyptian governorates, and the performance of the same hybrid varied according to each governorate's environmental factors, evaluation index, and subordinate function averages, which vary with location climate factors.

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

Treatment	Character	FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth Rate		C/L (No.)	CP (%)	PR (%)
						4th instar	5th instar			
C	Hy G	8.834	30.855	4.916	9.304	0.142	0.087	173.200	90.400	90.500
	Hy K	8.917	30.917	3.100	9.333	0.147	0.088	176.000	92.900	91.250
	Hy H	9.134	31.405	3.667	9.158	0.139	0.083	189.200	82.300	87.500
P	Hy G	8.834	30.855	2.267	8.469	0.141	0.086	172.100	84.900	90.750
	Hy K	8.937	30.959	13.750	4.650	0.146	0.087	174.400	87.333	91.500
	Hy H	8.988	31.009	6.359	11.010	0.137	0.074	185.700	72.733	89.000
N	Hy G	9.000	30.500	3.100	15.867	0.140	0.081	186.233	75.800	87.750
	Hy K	9.137	30.638	5.857	13.317	0.145	0.082	193.600	79.100	90.000
	Hy H	9.200	30.700	5.156	12.367	0.135	0.070	195.900	75.167	87.000
M	Hy G	10.675	33.696	7.117	18.433	0.136	0.058	201.250	70.700	81.500
	Hy K	10.792	33.792	2.600	14.300	0.142	0.061	201.300	73.400	83.000
	Hy H	10.667	33.688	7.083	19.733	0.134	0.056	215.200	69.900	73.500
F (Treatment X Hybrid)		1.200	0.070	57.280**	5.280**	0.020**	1.230	0.460	28.880**	0.460
LSD 5%		**-**	**-**	**3.946**	**3.796**	**0.014**	**-**	**-**	**2.784**	**6.283**

Table 5: Cont.

Treatment	Character	DCP (%)	C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop	
								(No)	(g)
C	Hy G	1.327	1.651	0.310	18.844	1.271	3.506	9040.000	14950.614
	Hy K	2.100	1.721	0.355	20.701	1.297	3.973	9290.000	16003.125
	Hy H	0.883	1.621	0.297	18.355	1.254	3.344	8230.000	13371.242
P	Hy G	1.388	1.614	0.291	18.105	1.253	3.298	8490.000	13704.864
	Hy K	1.999	1.675	0.311	18.665	1.293	3.483	8733.333	14637.449
	Hy H	0.776	1.567	0.276	17.680	1.222	3.066	7273.333	11405.552
O	Hy G	0.277	1.529	0.270	17.608	1.190	2.995	7580.000	11581.552
	Hy K	1.665	1.529	0.282	18.569	1.177	3.091	7910.000	12092.582
	Hy H	0.943	1.459	0.263	18.137	1.126	2.860	7516.667	10973.117
M	Hy G	1.333	1.388	0.242	17.437	1.076	2.280	6570.000	9099.657
	Hy K	1.443	1.460	0.254	17.576	1.136	2.374	7340.000	10709.298
	Hy H	1.721	1.269	0.205	16.227	0.994	1.925	6990.000	8851.806
F (Treatment X Hybrid)		0.290	4.710**	8.200**	7.190**	4.500**	6.790**	41.140**	39.780**
LSD 5%		**-**	**0.049**	**0.011**	**0.606**	**0.044**	**0.121**	**317.520**	**491.270**

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

Also, Hosamani *et al*. (2022) reported that, season fluctuations and environment conditions have the significant effect at quality of multivoltine silkworm crops, inclusive (cocoon, shell) weight, and shell %, managing temperature and humidity is crucial to sustained seed cocoon formation in basic seed farms, as environmental variables fluctuate daily and seasonally.

The Differentiation between interactions of some silkworms, *B. mori* rearing techniques, silkworm hybrids, and silkworm instars were registered in Table 6. Insignificant differences were noted for 5th instar duration, all larvae duration, 5th instar growth rate, pupation percentage, and double cocooning percentage. While there were high significant variations for young and grown larval mortality, growth rate 4th instar, numbers cocoons/liters, cocooning percentage, cocoon weight, cocoon shell weight, cocoon shell percentage, pupae weight, the productivity of silk, yield cocoons by number and weight. The improvement in traits under enveloped treatments 1 and 2 because of providing the 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 those found by Gowda and Reddy (2007), who mention that the fluctuation in humidity through grown instars has an adverse impact on cocoon weight, cocoon shell weight, filament length, and raw silk percentage. Sarker (2018) reported that the humidity of the rearing lab may affect the quality of mulberry fed to silkworm larvae in different instars; the maximum values of leaf moisture were recorded with tender leaves, silkworm larvae take water only from leaf, leaf nutrient status greatly influences. 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.

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

Treatment	Character		FD (days)	WLD (days)	YLM (%)	GLM (%)	Growth rate 4th instar	Growth rate 5th instar	C/L (No.)	CP (%)	PR (%)
C	Hy G	Y	8.667	30.667	8.499	2.733	0.120	0.086	182.400	85.600	91.000
		W	9.000	31.042	1.333	15.875	0.164	0.087	164.000	95.200	90.000
	Hy K	Y	8.833	30.833	4.600	10.333	0.129	0.087	179.200	89.600	92.000
		W	9.000	31.000	1.600	8.333	0.166	0.088	172.800	96.200	90.500
	Hy H	Y	8.767	31.767	5.733	8.000	0.117	0.083	181.700	78.600	89.000
		W	9.500	31.042	1.600	10.315	0.161	0.083	196.700	86.000	86.000
P	Hy G	Y	8.667	30.667	3.333	8.533	0.119	0.086	181.200	82.200	90.500
		W	9.000	31.042	1.200	8.405	0.162	0.087	163.000	87.600	91.000
	Hy K	Y	8.875	30.875	6.667	7.933	0.128	0.088	177.200	85.000	91.000
		W	9.000	31.042	20.833	6.384	0.165	0.072	171.600	89.667	92.000
	Hy H	Y	8.976	30.975	6.384	7.733	0.115	0.076	180.200	70.600	89.000
		W	9.000	31.042	6.333	14.286	0.159	0.080	191.200	74.867	89.000
N	Hy G	Y	9.000	30.000	5.800	10.533	0.118	0.080	188.800	74.400	88.500
		W	9.000	31.000	0.400	21.200	0.161	0.083	183.667	77.200	87.000
	Hy K	Y	9.275	30.275	4.933	16.367	0.125	0.080	200.000	79.800	92.000
		W	9.000	31.000	6.780	10.267	0.164	0.084	187.200	78.400	88.000
	Hy H	Y	9.400	30.400	5.867	16.267	0.113	0.069	204.000	77.000	87.000
		W	9.000	31.000	4.445	8.467	0.158	0.072	187.800	73.333	87.000
M	Hy G	Y	11.349	33.349	1.233	19.867	0.111	0.055	199.100	70.000	78.000
		W	10.000	34.042	13.000	17.000	0.160	0.060	203.400	71.400	85.000
	Hy K	Y	11.583	33.583	4.600	13.800	0.120	0.059	201.800	75.000	80.000
		W	10.000	34.000	0.600	14.800	0.163	0.062	200.800	71.800	86.000
	Hy H	Y	11.333	33.333	9.333	19.800	0.109	0.054	223.200	72.200	63.000
		W	10.000	34.042	4.833	19.667	0.158	0.058	207.200	67.600	84.000
F (treatment X HybridX Instar)			0.030	0.100	49.420**	17.110**	0.180	0.040	2.990**	4.120**	0.600
LSD 5%			**-**	**-**	**3.914**	**4.738**	**-**	**-**	**11.820**	**4.394**	**-**

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

Table 6: Cont.

Treatment	Character		C W (g)	CSW (g)	CSR (%)	PW (g)	SP (cg/day)	Cocoon Crop (No)	Cocoon Crop (g)
C	Hy G	Y	1.597	0.299	18.7535	1.227	3.453	8560.000	13667.153
		W	1.705	0.320	18.935	1.315	3.559	9520.000	16234.075
	Hy K	Y	1.678	0.320	19.1757	1.288	3.618	8960.000	15030.221
		W	1.765	0.390	22.225	1.305	4.329	9620.000	16976.029
	Hy H	Y	1.539	0.288	18.624	1.181	3.286	7860.000	12098.662
		W	1.703	0.306	18.085	1.327	3.403	8600.000	14643.822
P	Hy G	Y	1.612	0.293	18.197	1.249	3.375	8220.000	13248.092
		W	1.617	0.290	18.013	1.257	3.220	8760.000	13248.092
	Hy K	Y	1.624	0.305	18.858	1.249	3.436	8500.000	13804.170
		W	1.726	0.318	18.4726	1.338	3.531	8966.66	15470.728
	Hy H	Y	1.540	0.275	17.9665	1.196	3.059	7060.000	10873.388
		W	1.595	0.277	17.393	1.248	3.073	7486.667	11937.715
O	Hy G	Y	1.594	0.284	17.764	1.240	3.152	7440.000	11856.161
		W	1.465	0.256	17.452	1.139	2.839	7720.000	11306.944
	Hy K	Y	1.500	0.281	18.825	1.149	3.027	7980.000	11970.287
		W	1.558	0.284	18.314	1.204	3.155	7840.000	12214.877
	Hy H	Y	1.491	0.261	17.677	1.159	2.781	7700.000	11478.413
		W	1.427	0.265	18.598	1.093	2.939	7333.333	10467.820
M	Hy G	Y	1.346	0.231	17.200	1.045	2.033	7000.000	9418.500
		W	1.430	0.253	17.674	1.108	2.526	6140.000	8780.814
	Hy K	Y	1.421	0.246	17.435	1.105	2.123	7500.000	10659.150
		W	1.499	0.263	17.717	1.166	2.626	7180.000	10759.445
	Hy H	Y	1.193	0.204	17.210	0.919	1.802	7220.000	8615.265
		W	1.345	0.205	15.244	1.070	2.048	6760.000	9088.347
F (treatment X HybridX Instar)			4.170**	4.490**	10.100**	6.910**	5.820**	3.690**	7.810**
LSD 5%			**0.0674**	**0.015**	**0.8355**	**0.0599**	**0.162**	**470.860**	**1056.900**

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

Differentiation between interactions of some silkworm, *B. mori* rearing techniques treatments, and sexes were found in Table 7. There were insignificant differences between treatments for characters of (cocoon, cocoon shell, and pupa weight), cocoon shell ratio, and silk productivity. Regardless of insignificant, 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 coincide with the data of Parrey and Lone (2018), who explored the impact of temperature and humidity on silkworm growth and development. They reported that natural component differences have a significant effect on silkworm cocoon productivity, including cocoon weight, shell weight, and cocoon shell ratio.

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

Character / Treatment	CW (g) Female	CW (g) Male	CSW (g) Female	CSW (g) Male	CSR (%) Female	CSR (%) Male	P W (g) Female	P W (g) Male	SP (cg/day) Female	SP (cg/day) 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
N	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, N, and M (Treatments) & (*) significant at 0.05, (**) highly significant at 0.01.

Adjusting temperature & relative humidity levels is crucial for effective cocoon production due to daily and seasonal variations in environmental conditions. Akinwande (2022) recorded that fluctuations in the temperature's degrees affect silkworm breeding. This investigation by Offord *et al*. (2016) proved that climate factors influenced the cocoon characters. Temperature affects the overall shape, and the cocoon color affects humidity. Temperature impacts cocoon shape, stiffness, and strength, i.e., spinning behavior. Cocoon coloration may be influenced by relative humidity or tanning treatments. The water concentration in a cocoon affects sericin dispersion and stiffness but not toughness.

Differentiation between interactions of some silkworm, *B. mori* hybrids, and sexes for cocoon traits (Table 8). The differences between treatments were insignificant except for the cocoon shell percentage trait. Regardless of the significance, Hy G and Hy K were the best hybrids for both sexes. The former results are in agreement with the findings of Sharma *et al*. (2018) reared the chawki rearing at room temperature, the young larval duration and moulting period were prolonged, the leaf consumption was more up to 3.5 Kg, the size of chawki worms was comparatively small and less weight was than the chawki rearing in optimum temperature. Whereas the decline and variations in the temperature degrees affected the growth and development of chawki rearing in late ages. The duration of the larvae was observed as 28 days. (Cocoon weight 2.22 g, shell weight 0.5 g, shell ratio percentage 22 %, and cocoon yield was 18.75 Kg per 10,000 larvae. Neelaboina *et al*. (2020) studied the performance of eleven bivoltine silkworm breeds under Kashmir climatic conditions in different seasons; the evaluation index values for five strains performed well in all three seasons. The hybrid of APS_4 has the best Spring and Summer seasons, whereas CSR_{50} recorded evaluation index values above 50 in summer and autumn only. The performance of breeds was significantly affected by the changes in the climate conditions during different seasons.

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

Character	CW (g)		CSW (g)		CSR (%)		P W (g)		SP (cg/day)	
Hybrid	**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: (*) 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 and cocoon shell ratio, while the difference was insignificant for cocoon shell weight and silk productivity. Results revealed that whole instars acquired better data than young instars for the weight of the cocoon, the weight of the cocoon shell, the cocoon shell ratio, pupae weight, and silk productivity for both sexes. They could be agreeing with the suggestion of Aruga and Watanabe, (1964), who suggested that silkworms are known to gain resistance with age, the early instars are comparably more sensitive to pathogens and decreases with larva maturing from first to fourth instars hence, temperature is an external element impacting the susceptibility of silkworm. The adapted temperature is 25°C higher or lower and tends to act as stress and increase the larval susceptibility to pathogens, thus reducing the cocoon indices. Islam and Rahman (2018) reared the M_2P_2 variety in a digitalized environmental growth chamber at different temperature regimes (25°, 28°, 30°, 32°, 35° and 38°C) and symmetric 60-95% relative humidity. The rise in temperature and humidity significantly reduced the larval developmental duration. Environmental factors and every larval duration trait have obvious negative coefficients of correlation means, further suggesting that the reproductive biology of the silkworm was negatively impacted by rising temperatures and relative humidity.

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

Character	CW (g)		CSW (g)		CSR (%)		PW (g)		SP (cg/day)	
Treatment	**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: (*) 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. There were insignificant differences in shell weight, cocoon shell ratio, and silk productivity characters. Treatments C and P (Envelope 1 and 2) were the best for whole instars, followed by the 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. Also, Barman and Das (2011) reported that the use of the polythene sheet and water-soaked foam bads maintenance of the leaf freshness of plant (*Persea bombycina* Kost) in rearing early stages indoor of *Antheraea assamensis*.

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

Treatment	Character	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, N, and M (Treatments) &&Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant

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, and 4 in the young instars and Figs 5,6,7, and 8 in whole instars. Also, Hussain *et al*. (2011c) evaluated economic cocoon characters for eleven silkworms inbred reared at various temperatures & relative humidity for three hrs. through grown instars. The silkworm lines fared far better when the larvae were raised at 25°C and 70–80% relative humidity, but nearly all silkworm lines did poorly after three hours of exposure to higher temperatures. When raised in instars at varying temperatures (25, 30, and 35◦C), larvae exposed to reduced humidity (55%) produced fewer cocoons. Barcelos *et al*. (2020) studied opportunities to enhance the environmental effect of mulberry and silk cocoon output in Brazil, Substitution raffia sacks with jute sacks or cotton sacks, replacing incandescent light bulbs in the barn with LED ones, and utilizing Kraft paper to cover silkworm raising beds and maintain a steady temperature. To reduce the effect of Kraft paper manufacturing, consider switching to a different form of paper or substance. Possible options include newspaper, nonwoven fabric (TNT), or lightweight, breathable fabrics, even though several suitable and customized chances to potentially lessen environmental consequences were found.

Table 11. Described the differentiation between sexes and between interactions of treatments, hybrids, and sexes of the silkworm, *B. mori*, and for cocoon traits. Highly significant 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. Insignificant differences were detected for cocoon shell weight, cocoon shell ratio, and silk productivity traits. 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 Rajan *et al*. 1995 & Ghazy, 2008, who discovered that raising silkworm larvae in polythene increased the average cocoon character.

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

Treatment	Character	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
N	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	
F (Treatment X Hybrid X Sex)		2.530*		0.080		1.440		3.250**		0.090	
LSD 5%		**0.058**		-		-		**0.050**		-	

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

Also, Ubaydullaevich and Ugli (2016) created three different methods to save the optimum temperature & relative humidity for rearing hybrid from the first to the fifth instar by using a damp cloth and polyethylene film fabric, the polyethylene film has been found to save mulberry leaf consumption by 15- 19% and reduced the larval duration by 2.7-4.0 days due to keep the temperature and humidity from sharp changes in temperate region. Hazarika *et al*. (2023) evaluated the performance of six developed heat shock technology hybrids for the first time at farmers, hybrids performed superior cocoon yield and high fecundity.

Data in Table 12. 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. While there were insignificant for the remaining characters. Regardless of insignificance, 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), who 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 being 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 as described by LakshminarayanaReddy *et al*. (2015) fluctuations in environmental factors significantly affected the silkworm larvae and silk gland growth, hybrids are more resistant to high temperature and low humidity, but maintaining the humidity around of 80% is preferred to normal development. Rahmathulla *et al*. (2016) proved that the growth rate of 4th and 5th larvae increased with an increase in leaf moisture, a positive correlation between the moisture content of leaf and larva to traits of growth rate, larval weight, single cocoon weight, single shell weight, and average filament length were recorded.

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 to preserve the freshness of mulberry leaves for a long time to be available for feeding the larvae.

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.

Treatment	Character		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
N	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, N, and M (Treatments) &Y, W (Yong and Whole Instars) & (*) significant at 0.05, (**) highly significant at 0.01.

4. Conclusion

From the figures of temperature degrees and relative humidity percentages, it is confirmed that the treatments of Enveloped type 1 and Enveloped type 2 were the best, whereas save the best temperature and relative humidity needed to larvae. As well as save 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.

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