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Evaluation of Some Potential Silkworm *Bombyx mori* L. Hybrids in Different Locations under Temperate Conditions

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Abstract: Silkworms, *Bombyx mori* L. consider commercial insects due to their economic value as silk-producing insects. Hybrid vigour was discovered in silkworms. Silkworm breeding has made for improving the output of hybrids. So, all commercial eggs are hybrids. Six local silkworm hybrids were obtained from hybridizations of ten local races and evaluated in two Egyptian governorates (Giza and Daqahlyia). Fourteen biological and economic characters of mulberry silkworm take into consideration. Fifth larvae duration (FD), Total larvae duration (LD), and mortality percentage (MP) were recorded. Also, cocooning percentage (CP), pupation ratio (PR), double cocooning percentage (DCP), number of cocoons/Liter (C/L), cocoon crop by number (Crop/N), cocoon crop by weight (Crop/W), fresh cocoon weight (CW), cocoon shell weight (CSW), pupae weight (PW), cocoon shell ratio (CSR), and silk productivity (SP) parameters were evaluated. Data were analyzed by adopting modified equations of evaluation index and subordinate function. The results clarified that there isn't a single hybrid better for all studied characters altogether. The performance of the same hybrids differed according to the governorate. In addition, the evaluation index and subordinate function values differ with location.

Key words: Local hybrids · Mean performance · Evaluation index · Subordinate function · Silkworm · *Bombyx mori* L.

INTRODUCTION

The silkworm, *Bombyx mori* L., is an economical insect that produces natural silk and contributes to a large percentage of the world's natural silk production [1]. Successful cocoon production depends on rearing suitable silkworm breeds or hybrids recommended for a season /region.

Mulberry silkworm hybridization began in China and Japan in the 19th century. The main purpose of silkworm hybridization is to develop new strains resistant to diseases, with high productivity potential, and environment adaptive so sericulturists in all sericulture countries play an important role to improve the genetic potential through breeding [2, 3].

Silkworm breeding aims at the overall improvement of silkworm breeds for commercial exploitation by the natural and socio-economic situation of Egypt. The breeds tried to improve multiple quantitative and qualitative traits in silkworms. Sericulture activities are a potential sector of agriculture to raise the profit of the farmers and also generate foreign exchange for our country.

The success of the silk project depends on many factors such as mulberry yielding and silkworm varieties to get a high crop of cocoons. Genetic diversity in the silkworm populations is affected by improved economic characters and suitability for climatic conditions to make silk production sustainable [4]. The level of heterosis present in a cross-breed population can be influenced by environmental factors in every location [5]. Good cocoon crops depend on many factors biotic and abiotic factors that play an important role in silkworm productivity.

Temperature and humidity play a very important role in the life cycle of silkworms. Grown silkworm larvae (4th and 5th instar) are more sensitive to temperature [6, 7]. Jumagulov *et al*. [8] registered that temperature and relative humidity affect the duration and viability of the silkworm larvae and cocoon yields fall sharply and their quality does not meet demand. The quantitative characters of silkworms are not only controlled by genes but also influenced by environmental factors such as temperature, humidity, and photoperiod [9, 10].

Egypt imports its needs from silkworm eggs every year. The importation process faced many difficulties in

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addition to the need for foreign currency, which may lead to the failure of importation, which happened in 2003 as mentioned by Ghazy [11]. Scientists of the Sericulture Research Department (SRD), Giza started the breeding program in 1994 to develop some high-yielding races of silkworms producing high quality and quantity of silk [12].

In the last few years, there has been a growing interest in determining the best silkworm hybrid under climate conditions for each governorate in Egypt [13-15]. Silkworm breeders have to pay more attention to the development of quality characters of silkworm, *B. mori* L., to identify hybrids for the best characters therefore, the research organizations and government should be given prime importance to the sericulture industry especially breeding silkworm races of our country to produce silk comparable to Seri-culturally advanced countries.

The main objective of this experiment is to test some local hybrids under two different governorate conditions and determine the best hybrid for each governorate by means of a modified evaluation index and subordinate function formulae.

MATERIALS AND METHODS

Hybridizations: In this experiment ten races of the silkworm, *Bombyx mori* L. collected from the breeding program of the Sericulture Research Department Plant Protection Research Institute Agriculture Research Center (G_{155}, H_{245}, J_{234}, J_{444}, K_{111}, L_{252}, O_{111}, $RBmch_3$, $RBmch_4$, and $RBPJ_2$). The maternal egg races were reared to collect a decent weight of eggs throughout the Spring season. Egg cards are hatched through methods of artificial hatching in the Autumn season [16]. Hybridizations were made between selected races. Six hybrids were obtained from hybridization coded as follows:

1. H_{245} X G_{155} coded as Hy A.
2. $RBmch_3$ X L_{252} coded as Hy B.
3. $RBpj_2$ X G_{155} coded as Hy C.
4. O_{111} X J_{234} coded as Hy E.
5. K_{111} X $RBmch_4$ coded as Hy F.
6. J_{444} X K_{111} coded as Hy H.

All tested hybrids were reared in three replicates each replicate was counted of three hundred larvae for each hybrid in two selected governorates; Sericulture Research Department in Giza Governorate (G) and Sericulture station in El-Daqhalyia Governorate (D).

Rearing Young Instars: Young silkworm larvae mean first to third instar larvae were reared during the Spring season under laboratory conditions at 27± 2°C and 75 ± 5% temperature and relative humidity. Hatched larvae brushed in plastic trays and fed on chopped mulberry leaves *Morus alba* var canva-2 four times daily. Plastic sheets were used for the bottom and cover of the larvae, and larvae were surrounded with wet foam [17]. After each moult larvae were dusted with disinfectants as described by Hosny *et al*. [18].

Rearing Grown Instars: Grown silkworm larvae (4^{th} and 5^{th} instars) were fed with shoots of mulberry. Larvae were dusted with recommended disinfectant on particular days as described by [18]. Matured larvae were transferred in collapsible frames for montage then cocoons were collected after 7 days. The fifth larvae duration (FD), total larvae duration (LD), and mortality percentage (MP) were recorded for each replicate. From each hybrid, thirteen female and male cocoons were selected randomly to be evaluated by registered, cocooning percentage (CP), pupation ratio (PR), double cocooning percentage (DCP), number of cocoons/Liter (C/L), cocoon crop by number (Crop/N), cocoon crop by weight (Crop/W), fresh cocoon weight (CW), cocoon shell weight (CSW), pupae weight (PW), cocoon shell ratio (CSR) and silk productivity (SP) parameters.

- The mortality percentage was calculated by the following formula:

$$\text{Mortality Percentage} = \frac{\text{Number of dead larvae}}{\text{Total number of larvae}} \text{ X } 100$$

- The double cocoon percentage was measured according to Lea's [19] equation:

$$\text{Double cocoon percentage} = \frac{\text{Number of pupae made double cocoon}}{\text{Total number of pupae harvested}} \text{ X } 100$$

Hybrid Evaluation: The modified equation of the evaluation index and subordinate function by Ghazy [20] was used for evaluating all the tested hybrids.

A- The formulae of the evaluation index:

1- Formula of characters with positive direction:

$$\text{Evaluation index (EI)} = \frac{(A - B)}{(C \text{ X } 10)} + 50$$

2- Formula of characters with negative direction:

$$\text{Evaluation index (EI)} = 50 - \frac{(A - B)}{(C \text{ X } 10)}$$

Where:
A = Particular character value of the particular hybrid.
B = Mean value of the particular character of all the considered hybrids.
C = Deviation of Standard (n-1) for a particular character of all the considered hybrids.
10 = Unit of standard, 50 = Fixed value.

The superiority of hybrid genotypes impartially, a common of evaluation index is inevitably adopted giving equal emphasis to all the commercial economic characters. The average of evaluation index value fixed to select a hybrid genotype is over 50. Only the hybrids with an evaluation index value higher than 50 have been considered of good economic importance.

B - The formulae of the subordinate function:

Subordinate function (XU) = $(X_i - X_{worst}) / (X_{best} - X_{worst})$

Where:
XU = Subordinate function,
Xi = value of character for an examined genotype.
X_{worst} = The worst value of this parameter among all the tested genotypes.
X_{best} = The best value of this parameter amongst all the tested genotypes.

Hence, the worst value of parameter with positive directions is the lowest value and it is the highest value for parameters with negative directions. Also, the best value of positive direction parameters is the highest value, as well as in the same time it is the lowest value of the negative direction parameters.

RESULTS AND DISCUSSION

A. Performance of average values for six local hybrids reared in two different governorates Giza and Daqahliya: The Data in Table 1 showed the average values of fourteen characters for six local hybrids of the silkworm, *B. mori* L. reared in the Giza governorate. It is clear that three hybrids have the best results for twelve characters together these hybrids are HyGA, HyGB, HyGF, and HyGH. And hybrid HyGA has the best results for eleven characters.

Table 2 appeared the average values of fourteen characters for six local hybrids of *B. mori* reared in the Daqhliya governorate. The results showed that HyDF has the highest results for thirteen characters and HyDC for eleven characters. Whereas, hybrids of HyDA and HyDB have good results for nine characters altogether simultaneously.

The results in Table 1 and Table 2 indicated that the performance of the same hybrids differed according to

Table 1: Average values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Giza Governorate.

	Character									
	CW (g)		CSW(g)		PW(g)		CSR (%)		SP (cg/day)	
Hybrid	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Hy GA	2.282	1.856	0.373	0.347	1.839	1.440	16.379	18.745	4.244	3.919
Hy GB	1.896	1.709	0.327	0.343	1.499	1.296	17.232	20.109	4.086	4.288
Hy GC	1.704	1.433	0.283	0.255	1.351	1.108	16.661	17.906	3.144	2.832
Hy GE	1.569	1.383	0.284	0.272	1.214	1.041	18.319	20.142	3.160	3.021
Hy GF	1.961	1.811	0.335	0.324	1.556	1.417	17.037	17.899	3.721	3.598
Hy GH	1.705	1.484	0.318	0.287	1.318	1.128	18.518	19.842	3.532	3.186

Where: G: Giza; Hybrids: (A,B,C,E,F and H); Cw: cocoon weigh; CSW: cocoon shell weight; CSR: cocoon shell ratio; SP: (silk productivity.

Table 1: Continued

	Character								
Hybrid	FD (day)	LD (day)	MP (%)	CP (%)	PR (%)	DCP (%)	C/L (No)	Crop/N (No)	Crop/W (g)
Hy GA	9.250	29.000	25.000	74.000	100.000	1.773	144.000	7400.000	14784.278
Hy GB	10.370	31.000	15.000	85.000	100.000	2.403	160.000	8500.000	15458.917
Hy GC	9.500	33.375	16.000	76.000	95.833	0.000	186.400	7600.000	11710.180
Hy GE	10.000	31.000	15.000	70.000	98.333	1.977	185.600	7000.000	10337.707
Hy GF	10.000	30.000	10.000	90.000	100.000	6.983	152.800	9000.000	17074.437
Hy GH	9.000	28.000	3.000	83.000	96.667	7.437	165.600	8300.000	13450.449

Where: G (Giza); Hybrids (A,B,C,E,F and H); FD (fifth duration); LD (larval duration); MP (mortality percentage); CP (cocooning percentage); PR (pupation ratio); DCP (double cocooning percentage); C/L (number of cocoon per liter); crop/N (cocoon crop by number) and crop/w (cocoon crop by weight).

Table 2: Average values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Daqahliya Governorate.

	Character									
	CW (g)		CSW(g)		PW(g)		CSR (%)		SP (cg/day)	
Hybrid	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Hy DA	1.831	1.791	0.336	0.345	1.425	1.377	18.738	19.443	3.633	3.726
Hy DB	1.985	1.964	0.374	0.395	1.540	1.499	18.917	20.206	3.609	3.814
Hy DC	2.005	1.964	0.346	0.355	1.588	1.540	17.369	18.266	3.647	3.736
Hy DE	2.120	2.110	0.374	0.396	1.677	1.644	17.500	18.710	3.738	3.965
Hy DF	2.124	2.104	0.429	0.460	1.625	1.573	20.199	21.717	4.290	4.604
Hy DH	2.336	2.260	0.397	0.428	1.869	1.762	17.014	19.054	4.410	4.753

Where: D (Daqahliya); Hybrids (A,B,C,E,F and H); Cw: cocoon weigh; CSW: cocoon shell weight; CSR: cocoon shell ratio; SP: (silk productivity).

Table 2: Continued

	Character								
Hybrid	FD (day)	LD (day)	MP (%)	CP (%)	PR (%)	DCP (%)	C/L (No)	Crop/N (No)	Crop/W (g)
Hy DA	9.250	30.000	11.000	90.000	90.000	0.737	154.417	9000.000	16279.661
Hy DB	10.370	32.370	15.000	88.000	95.278	2.274	159.472	8800.000	17376.280
Hy DC	9.500	30.000	13.330	90.000	95.556	0.000	165.200	9000.000	17865.130
Hy DE	10.000	31.620	16.660	79.000	85.000	0.000	180.600	7900.000	16712.558
Hy DF	10.000	31.000	13.000	90.000	98.333	3.600	164.000	9000.000	19024.238
Hy DH	9.000	28.830	25.000	85.000	99.167	3.773	167.800	8500.000	19532.680

Where: D (Daqahliya); Hybrids (A, B, C, E, F and H); FD (fifth duration); LD (larval duration); MP (mortality percentage); CP (cocooning percentage); PR (pupation ratio); DCP (double cocooning percentage); C/L (number of cocoon per liter); crop/N (cocoon crop by number) and crop/w (cocoon crop by weight).

the governorate. Hence HyGH, HyGF, and HyGB showed high results for twelve characters while in the Daqhliya governorate HyDF and HyDC represented the best results.

These results are in correspondence with those found by Ghazy [21] who evaluated sixteen hybrids and clarified that none of the sixteen hybrids acquired the best performance for all tested traits. Mahmoud and Ghazy [13] evaluate some imported hybrids and different local hybrids they stated that the same hybrids have different genetic expressions in different locations as well as the genetic expression of local hybrids depends on location. In addition, thirteen single local hybrids were reared in Qalubiya and Alexandria governorates, and the performance of the thirteen hybrids under the Qalubiya conditions is better than the performance of the same hybrid reared in the Alexandria governorate [14, 22]. Ghazy *et al*. [15] have also, noted that silkworm larvae are very sensible insects for environmental conditions fluctuations in every location. So, silkworm hybrids should be adaptable to climatic conditions and fluctuations in every location. As well as, as suggested by Fouad [23] characters of silkworm rendering vary in performance depending on environmental conditions. Therefore, it is very much important to provide the optimum environmental conditions because the economic characters are greatly influenced by the environmental conditions than the silkworm genotype.

The performance of the breed itself will be the best indicator in a given environment [24]. The biological and economic characters of silkworms are influenced by different factors such as genetic control and environmental conditions. Therefore, to enhance the productivity of silkworms must obtain a suitable hybrid with improving environmental conditions like nutrition and rearing conditions [25, 26].

B. Evaluation Index Values of Six Local Hybrids for Silkworm *Bombyx mori* L. Estimate in Giza and Daqahliya Governorates: Values of the evaluation index for fourteen traits of six local hybrids silkworm, *B. mori* L. reared in the Giza governorate were found in Table 3. It is obvious that no single hybrids earned the best values for all characters under this investigation. From the six hybrids, only four hybrids were better (HyGH, HyGA, HyGB, and HyGC). Hybrids of HyGH and HyGA were better values for eleven and eight, characters together, while hybrids of HyGB and HyGC were the best average evaluation index for seven traits only.

Table 4 showed the average values of evaluation index for all traits of six local hybrids of silkworm *B. mori* L. reared in Giza governorate. The data cleared that

Table 3: Evaluation index values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Giza Governorate.

	Character									
	CW (g)		CSW(g)		PW(g)		CSR (%)		SP (cg/day)	
Hybrid	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Hy GA	65.110	49.674	55.853	46.864	66.416	50.411	36.544	44.944	55.006	45.102
Hy GB	49.421	48.595	49.917	49.381	49.340	48.436	50.087	51.573	49.922	49.472
Hy GC	53.942	48.824	54.566	46.494	53.629	49.463	51.655	44.319	53.819	47.344
Hy GE	52.495	46.588	52.231	47.278	52.439	46.517	48.952	48.429	51.865	47.938
Hy GF	49.223	49.549	51.592	46.261	48.749	50.414	53.072	43.164	51.332	47.167
Hy GH	53.956	41.864	62.450	50.387	51.949	39.913	64.355	69.109	60.411	50.294

Where: G: Giza; Hybrids: (A, B, C, E, F and H); Cw: cocoon weigh; CSW: cocoon shell weight; CSR: cocoon shell ratio; SP: (silk productivity).

Table 3: Continued

	Character								
Hybrid	FD	LD	MP	CP	PR	DCP	C/L	Crop/N	Crop/W
Hy GA	50.000	50.000	50.000	54.512	50.000	50.014	44.640	51.608	42.676
Hy GB	73.740	55.801	57.715	55.639	50.000	49.203	48.660	54.823	49.347
Hy GC	46.043	38.398	53.086	51.128	53.321	50.000	50.268	51.608	51.007
Hy GE	26.260	44.199	42.285	27.442	56.643	50.432	51.072	46.785	49.970
Hy GF	42.087	50.000	46.914	44.361	50.001	50.338	59.916	48.392	49.524
Hy GH	65.827	55.801	53.086	53.384	63.285	50.027	51.072	51.608	48.998

Where: G (Giza); Hybrids (A, B, C, E, F and H); FD (fifth duration); LD (larval duration); MP (mortality percentage); CP (cocooning percentage); PR (pupation ratio); DCP (double cocooning percentage); C/L (number of cocoon per liter); crop/N (cocoon crop by number) and crop/w (cocoon crop by weight).

Table 4: Average of evaluation index for all characters of six local hybrids of silkworm *Bombyx mori* L. reared in Giza Governorate.

Hybrid	Average of Evaluation Index
Hy GA	48.072
Hy GB	47.359
Hy GC	47.935
Hy GE	45.951
Hy GF	46.477
Hy GH	49.687

Where: G (Giza); Hybrids (A, B, C, E, F and H).

there is no hybrid over 50 from all hybrids under this investigation. But hybrids of HyGH followed by HyGA, HyGB, and HyGC have the highest average evaluation index for all parameters under study.

The results in Table 5 summarized the evaluation index values of fourteen characters for six local hybrids of the silkworm, *B. mori* L. reared in the Daqhliya governorate. No hybrid has the best values of the evaluation index for all tested characters. Hybrids of HyDH and HyDE have better results for ten characters together. While HyDA has the best results for seven characters under the experiment.

Recorded data in Table 6 showed the average evaluation index of all characters in Daqhaliya governorate. The highest averages of the evaluation index were registered for the hybrid of HyDA, HyDE, HyDH, and HyDC. The results of Tables 3 and 5 reveal that there is not a single superior hybrid for all the studied traits. Also, the evaluation index is differing with the location.

As mentioned in Tables 4 and 6 it is clear that the total averages of the evaluation index were changed according to the location of the same hybrid. But mostly the evaluation index differed along with the location of the hybrid. These results are coincidental this was found by Ghazy *et al*. [27] who found that local hybrids of Giza A, C, D, and F earned the best evaluation index values. Also, Ghazy [28] determined the superiority of eleven local hybrids for silkworm *B. mori*, there is no hybrid that has the best evaluation index values for all tested characters altogether. Evaluation index values resulted that seven hybrids being superior to fifteen tested hybrids [15]. The results offered by Fouad [23] estimated the regional effect and evaluation index function of three mulberry silkworms, *B. mori* hybrids in three different locations Giza, Qalubyia, and Sohag Governorates. The results approved that, the evaluation index depends on the hybrids which represented the genetic factor, the locations that represented the environmental factors, and the interactions between genetics and environment. In similarity, Bajwa *et al*. [29] who estimated the heterosis of ten bivoltine hybrids and their parents by using eleven biological and quantitative traits using multiple evaluation index and cumulative sub-ordinate function. All hybrids produced the best evaluation index for filament length,

Table 5: Evaluation index values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Daqahliya Governorate.

	Character									
	CW (g)		CSW(g)		PW(g)		CSR (%)		SP (cg/day)	
Hybrid	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Hy DA	60.797	65.328	50.625	60.788	61.857	65.474	40.379	49.485	50.639	64.772
Hy DB	51.962	49.039	51.327	48.592	51.876	49.250	49.030	48.964	51.210	51.477
Hy DC	41.830	55.001	44.760	52.487	42.121	55.360	51.545	47.047	44.783	72.158
Hy DE	51.008	52.358	51.484	51.191	50.780	52.522	51.547	49.522	51.403	57.386
Hy DF	52.414	47.273	37.398	47.338	55.573	47.470	34.423	48.686	38.082	42.614
Hy DH	53.350	52.710	56.220	52.330	52.30	52.600	53.920	50.720	56.540	64.770

Where: G: Giza; Hybrids: (A,B,C,E,F and H); Cw: cocoon weigh; CSW: cocoon shell weight; CSR: cocoon shell ratio; SP: (silk productivity).

Table 5: Continued

	Character								
Hybrid	FD	LD	MP	CP	PR	DCP	C/L	Crop/N	Crop/W
Hy DA	35.228	61.262	47.746	45.794	50.000	49.905	49.587	44.655	62.498
Hy DB	48.523	44.369	38.730	56.309	45.029	50.545	53.163	52.673	52.194
Hy DC	27.842	72.524	54.508	47.897	40.057	50.000	56.311	47.327	46.594
Hy DE	42.614	44.369	45.492	52.103	67.897	50.000	56.559	52.673	53.566
Hy DF	57.386	44.369	54.508	71.031	44.034	52.641	52.475	41.982	44.446
Hy DH	35.230	44.370	45.490	52.103	51.491	50.310	49.130	52.670	55.380

Where: D (Daqahliya); Hybrids (A,B,C,E,F and H); FD (fifth duration); LD (larval duration); MP (mortality percentage); CP (cocooning percentage); PR (pupation ratio); DCP (double cocooning percentage); C/L (number of cocoon per liter); crop/N (cocoon crop by number) and crop/w (cocoon crop by weight).

Table 6: Average of evaluation index for all characters of six local hybrids of silkworm *Bombyx mori* L. reared in Daqahliya Governorate.

Hybrid	Average of Evaluation Index
Hy DA	53.517
Hy DB	49.698
Hy DC	50.008
Hy DE	51.814
Hy DF	48.113
Hy DH	51.665

Where: D (Daqahliya); Hybrids (A, B, C, E, F and H).

while seven hybrids earned a good evaluation index for fecundity, larval body weight, pupation rate, cocoon shell ratio, and cocoon yield. So, there is no hybrid better for all traits altogether. The results of the present study indicate that the evaluation index about each hybrid is a very important tool that explained the manifestation of hybrid vigour in respect of each of the traits independently and in conjugation with the other. This is in agreement with the observations of Gowda *et al*. [30] who evaluate 21 hybrids, six promising cross hybrids are promising, evaluation index values, and heterosis for the majority of the traits in three different seasons (climatic conditions). In similarity, ranking of the breeds based on dependent traits and multiple trait evaluation index system are found to be more useful in evaluating the performance of silkworms [31].

C. Subordinate Function Values of Six Local Hybrids of Silkworm *Bombyx mori* L. Reared in Giza and Daqahliya Governorates: Data illustrated in Table 7 showed the subordinate function for fourteen characters of six silkworms, *B. mori* L. local hybrids reared in the Giza governorate. Results revealed that HyGA and HyGB have the best results for twelve characters while hybrid HyGF has better results for eleven characters only. The cumulative subordinate function of all parameters for six silkworm local hybrids reared in the Giza governorate are illustrated in Table 8 both hybrids of HyGA, HyGF, and HyGB have the highest cumulative subordinate function values.

The recorded data in Table 9 clarified the subordinate function values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Daqahliya Governorate indicating that, hybrids of HyDF followed by HyDC have best results for twelve and ten characters altogether respectively. Where HyDA and HyDH have the best data for eight characters.

Data that appeared in Table 10 illustrated cumulative subordinate function for all characters of six local hybrids of silkworm *B. mori* L. reared in the Daqhliya governorate it is obvious that the highest values were earned by HyDF followed by HyDH and HyDC. No single hybrid was better for all traits together. The best results of

Table 7: Subordinate function values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Giza Governorate.

	Character									
	CW (g)		CSW(g)		PW(g)		CSR (%)		SP (cg/day)	
Hybrid	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Hy GA	0.681	0.960	0.865	0.921	0.661	0.926	0.524	0.588	0.869	0.848
Hy GB	0.581	0.708	0.692	0.814	0.581	0.652	0.403	0.746	0.913	0.950
Hy GC	0.272	0.171	0.293	0.104	0.304	0.192	0.290	0.419	0.277	0.082
Hy GE	0.151	0.141	0.357	0.235	0.153	0.123	0.584	0.819	0.338	0.185
Hy GF	0.657	0.877	0.707	0.734	0.665	0.875	0.319	0.442	0.669	0.579
Hy GH	0.273	0.478	0.343	0.276	0.295	0.514	0.331	0.323	0.324	0.218

Where: G: Giza; Hybrids: (A, B, C, E, F and H); Cw: cocoon weigh; CSW: cocoon shell weight; CSR: cocoon shell ratio; SP: (silk productivity).

Table 7: Continued

	Character								
Hybrid	FD (day)	LD (day)	MP (%)	CP (%)	PR (%)	DCP (%)	C/L (No)	Crop/N (No)	Crop/W (g)
Hy GA	0.818	0.761	0.172	0.533	1.000	0.769	0.819	0.261	0.623
Hy GB	0.000	0.522	0.517	0.778	1.000	0.687	0.529	0.739	0.709
Hy GC	0.635	0.239	0.483	0.578	0.583	1.000	0.051	0.348	0.231
Hy GE	0.270	0.522	0.517	0.444	0.833	0.743	0.065	0.087	0.056
Hy GF	0.270	0.642	0.690	0.889	1.000	0.092	0.659	0.957	0.915
Hy GH	1.000	0.881	0.931	0.733	0.667	0.033	0.428	0.652	0.453

Where: G (Giza); Hybrids (A, B, C, E, F and H); FD (fifth duration); LD (larval duration); MP (mortality percentage); CP (cocooning percentage); PR (pupation ratio); DCP (double cocooning percentage); C/L (number of cocoon per liter); crop/N (cocoon crop by number) and crop/w (cocoon crop by weight).

Table 8: Cumulative subordinate function for all characters of six local hybrids of silkworm *Bombyx mori* L. reared in Giza Governorate.

Hybrid	Cumulative of Subordinate function
Hy GA	13.599
Hy GB	12.521
Hy GC	6.552
Hy GE	6.623
Hy GF	12.638
Hy GH	9.153

Where: G: Giza; Hybrids: (A, B, C, E, F and H).

cumulative subordinate function were recorded for HyDF followed by HyDH, HyDC, HyDB, and HyDA, respectively.

From the results of Tables 7 and 9 it was noticed that there is no single hybrid was the best for all parameters together for both governorates. These results are in agreement with Ghazy [28] who estimated the subordinate function in twelve silkworm hybrids. Who stated that seven hybrids acquired the best data of subordinate function values.

Registered data in Tables 8 and 10 showed the cumulative subordinate function for six hybrids in the two governorates. It is clear that the same hybrid has different values in different governorates. These results are in good agreement with studies by Fouad [32] which have evaluated five local and two imported hybrids. Hybrid Hy A registered the highest value of the subordinate function for most traits. Highest cumulative of subordinate function registered for G_2, Hy A, G_1, and Hy B hybrids.

D. Ranking of Local Cross Hybrids of Silkworm *Bombyx mori* L. Reared in Giza Governorate: The ranking of local cross silkworm hybrids averages of evaluation index and cumulative subordinate function reared in Giza and Daqahliya Governorates was founded in Tables 11 and 12

Table 9: Subordinate function values for fourteen characters of six local hybrids of silkworm *Bombyx mori* L. reared in Daqahliya Governorates.

	Character									
	CW (g)		CSW(g)		PW(g)		CSR (%)		SP (cg/day)	
Hybrid	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Hy DA	0.272	0.344	0.062	0.336	0.295	0.327	0.481	0.425	0.234	0.458
Hy DB	0.473	0.565	0.370	0.600	0.461	0.522	0.518	0.606	0.216	0.645
Hy DC	0.499	0.566	0.146	0.389	0.529	0.588	0.206	0.146	0.246	0.500
Hy DE	0.650	0.752	0.366	0.605	0.656	0.755	0.232	0.251	0.315	0.583
Hy DF	0.655	0.744	0.811	0.936	0.582	0.642	0.775	0.964	0.738	0.583
Hy DH	0.932	0.944	0.552	0.768	0.933	0.944	0.135	0.333	0.830	0.417

Where: D (Daqahliya); Hybrids (A, B, C, E, F and H); Cw: cocoon weigh; CSW: cocoon shell weight; CSR: cocoon shell ratio; SP: (silk productivity).

Table 9: Continued

	Character								
Hybrid	FD (day)	LD (day)	MP (%)	CP (%)	PR (%)	DCP (%)	C/L (No)	Crop/N (No)	Crop/W (g)
Hy DA	0.542	0.500	0.941	0.545	0.571	0.816	0.941	0.800	0.206
Hy DB	0.355	0.204	0.706	0.455	0.798	0.431	0.785	0.667	0.429
Hy DC	0.500	0.500	0.804	0.545	0.810	1.000	0.609	0.800	0.529
Hy DE	0.417	0.298	0.608	0.045	0.357	1.000	0.135	0.067	0.294
Hy DF	0.417	0.375	0.824	0.545	0.929	0.100	0.646	0.800	0.765
Hy DH	0.583	0.646	0.118	0.318	0.964	0.057	0.529	0.467	0.869

Where: D (Daqahliya); Hybrids (A, B, C, E, F and H); FD (fifth duration); LD (larval duration); MP (mortality percentage); CP (cocooning percentage); PR (pupation ratio); DCP (double cocooning percentage); C/L (number of cocoon per liter); crop/N (cocoon crop by number) and crop/w (cocoon crop by weight).

Table 10: Cumulative subordinate function for all characters of six local hybrids of silkworm *Bombyx mori* L. reared in Daqahliya Governorate.

Hybrid	Cumulative of Subordinate function
Hy DA	9.096
Hy DB	9.806
Hy DC	9.912
Hy DE	8.386
Hy DF	12.831
Hy DH	11.339

Where: D (Daqahliya); Hybrids (A, B, C, E, F and H).

Table 11: Ranking of local cross hybrids of silkworm *Bombyx mori* L. reared in Giza governorate.

Hybrid	Average of Evaluation Index	Serial number of Evaluation Index	Serial Number of Subordinate Function	Cumulative of Subordinate function
Hy GA	48.072	2	1	13.599
Hy GB	46.477	5	3	12.521
Hy GC	47.359	4	6	6.552
Hy GE	49.687	1	5	6.623
Hy GF	45.951	6	2	12.638
Hy GH	47.935	3	4	9.153

Table 12: Ranking of local cross hybrids of silkworm *Bombyx mori* L. reared in Daqahliya governorate.

Hybrid	Average of Evaluation Index	Serial number of Evaluation Index	Serial Number of Subordinate Function	Cumulative of Subordinate function
Hy DA	48.113	6	5	9.096
Hy DB	51.665	3	4	9.806
Hy DC	50.008	4	3	9.912
Hy DE	49.698	5	6	8.386
Hy DF	53.517	1	1	12.831
Hy DH	51.814	2	2	11.339

it was explained that hybrids reared in Giza governorate HyGH and HyGA have the nearest order. While in Daqahliya Governorate, HyDH and HyDF have the same order of evaluation index and subordinate function while the rest hybrids have the nearest orders. A similar approach is used for thirty new hybrid combinations and assessed by adopting evaluation index and subordinate function methods, five hybrid combinations would regard as promising and chosen for further laboratory evaluation [33]. Thirty-one lines were reared in different seasons to be evaluated by using the evaluation index and sub-ordinate function methods. Ten top-ranked lines were ascertained as potential parental strains [34].

CONCLUSION

This experiment was carried out because it was very necessary to produce new lines of silkworms that are resistant to our climate/location and adapt to the natural conditions with high productivity to reduce dependence on imports and provide hard currency. Six single hybrids are reared in Giza and Daqahliya governorates to evaluate. Data explain that there is not a single superior hybrid for all the traits studied. The performance of the same hybrids differed according to the governorate. Also, the evaluation index and subordinate function values differ with location. The previous results suggest that before using the silkworm hybrids in any governorate, it must be evaluated to determine the best hybrid for each location.

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