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New double hybrids of mulberry silkworm, *Bombyx mori* L. to be suitable for changed caused in Egyptian climate

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Abstract
Breeding program of sericulture research department in Egypt has created many new mulberry silkworm, *Bombyx mori* L. races. Hybridization was made between some races to produce single hybrids. Hybrids used to create double hybrids. Double hybrids are feature to be tolerant to un-stability conditions. Nowadays the Egyptian climates are changed. So that, farmers needs the tolerant hybrids for unstable climate to increase their crops.
Eleven races used for produced fifteen single hybrids. The resulted hybrids used to create fifteen double hybrids in the present investigation. Imported hybrid from Bulgaria reared as check parent.
The double hybrids are reared under the normal Egyptian conditions. Criteria of fifth and total larval duration were recorded. Mortality percentage, weights of fresh cocoon, cocoon shell and pupae were registered. Cocoon shell ratio, silk productivity, cocooning percentage, pupation ratio, Number of cocoon per liter, crop by number and weight were tested. All data were analyzed using check parent value. As well as modified of evaluation index and subordinate function.

Keywords: Double hybrids, new races, evaluation index, subordinate function, check parent, climate change

1. Introduction
Impact of climate change on sericulture required modifying for methods of rearing and development silkworm hybrids to be suitable for changes.
Genotypic expression affected by seasonal diversity of environmental component which expressed in phenotypic of silkworm traits such as cocoon characters. It is need to management of temperature and relative humidity for sustainable cocoon production (Rahmathulla, 2012) [11].
Sericulture scientists try to obtain hybrid suitable for the seasonal fluctuations conditions. They evaluate performance of bivoltine, multivoltine and multivoltine × bivoltine. Multivoltine × bivoltine hybrids represented very hardy with high survival rate and production under seasonal fluctuating conditions (Rao, 2006) [12].
Silkworm breeders evaluated the three- way and double hybrids comparison with single hybrids. They proved that, three way and double hybrids are suitable for climatic changes during Spring and Autumn seasons (Gowda *et al*. 2013, Gadgala and Singh 2016) [8, 4].
Mulberry silkworm is very sensitive insects for fluctuations in environmental factors such as temperature and humidity. This is may be return to very long time of domestication of silkworm. So, silkworm hybrids must be adoptable for the climatic conditions fluctuations.
Silkworm breeding program of Sericulture Research Department in Egypt attempt to development the sericulture through creation many new silkworm races. As well as using different type of hybridization, single, three way and double hybrids. To face the climatic changed caused in Egyptian climate, which affected on sericulture viz., survival of silkworm as well as the cocoon traits and affected on sustainability of cocoon production.
Environmental conditions represented the main factor which leads to success or un-success of the sericulture industry which divided to biotic and abiotic factors. Temperature factor among the abiotic affected on the growth and productivity (Ueda *et al*. 1975, Benchamin and Jolly, 1986) [15, 2].

Therefore, present work aims to development the silkworm hybrids to determine promising local silkworm hybrids comparison with the Bulgarian hybrid under changed Egyptian climate.

2. Material and Methods

Fifteen double hybrids were produced from hybridization between fifteen single hybrids. Ten races collected from breeding program of Sericulture Research Department used to produce single hybrids.

The hybridizations of double and single hybrids were illustrated in Table 1. Bulgarian (H_1 X UV X G_2 X V_2) hybrid was coded as H_{16}. It was consider as tester hybrids.

Mulberry leaves of *Morus indica* offered to silkworm larvae three times daily. The leaves were chopped during first three instars while whole leaves offered to fourth and fifth instars. Polythene sheets were applied during young silkworm to save optimal humidity of larvae. One gram of silkworm eggs of each hybrid was reared, during fourth five hundred larvae kept to count the mortality percentage.

The double hybrids are reared under the normal Egyptian conditions. Criteria of fifth (FD) and total larval duration (LD) were recorded. Mortality percentage (M %), weights of fresh cocoon (CW), cocoon shell (CSW) and pupae (PW) were registered. Cocoon shell ratio (CSR), silk productivity (SP), cocooning percentage (CP), pupation ratio (P %), No. of cocoon per liter (C⁄L), crop by number (C⁄No.) and weight (C⁄W.) were tested.

Silk productivity was estimated by using formula of Chattopadhyay *et al*. (1995) [3].

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

Where cg: Centigram

Cocooning percentage was calculated by using the formula of Goudar and Kaliwal (2000) [7] as follows:

$$\text{Cocooning percentage (\%)} = \frac{\text{No.of cocoons formed}}{\text{Total number of larvae kept}} \times 100$$

Cocoon shell ratio was calculated for both sexes according to Krishnaswami *et al*. (1972) [9].

$$\textit{Cocoon shell ratio} = \frac{\textit{Weight of cocoon shell}}{\textit{Weight of full cocoon}} \times 100$$

Evaluation index formulae of positive and negative directions:

Characters with Positive direction are:

$$\text{Evaluation index (EI)} = (\frac{(A-B)}{C} X10) + 50$$

Characters with negative direction are:

$$\text{Evaluation index (EI)} = 50 - (\frac{(A-B)}{C} X10)$$

Subordinate function

$X_U = (X_i - X_{worst}) / (X_{best} - X_{worst})$

Where: X_U = Subordinate Function, X_i = Measurement of character of a tested genotype, X_{worst} = the worst value of this character among all the tested genotypes, X_{best} = the best value of this character among all the tested genotypes

Heterosis was calculated according the formula of Singh *et al.* (2002) [14] as follows:

$$\text{Heterosis over CPV} = \frac{F_1 - CPV}{CPV} X100$$

Where CPV: Check Parent Value.

3. Results and discussion

3.1. Performance of different hybrids

Table 2 contains the mean performance of thirteen characters for fifteen silkworm and imported Bulgarian hybrid. It is obvious that, most of local hybrids have best performance for cocoon, shell and pupal weights and silk productivity for both sexes. As well as, number of cocoon per liter, fifth and total larval durations, and weight of cocoon crop per 10,000 larvae traits. While imported hybrid (H_{16}) earned higher average values for pupation ratio, cocooning percentage, mortality percentage and cocoon crop by number for 10,000 larvae characters. There are not single hybrid has higher data for all traits under study.

3.2. Check parent values for local hybrids

Figures from 1 to 5 represented the check parent value of fifteen local double hybrids. It is clearly that, most of local double hybrids superior over imported hybrid for weights of fresh cocoon, cocoon shell and pupae, silk productivity, No. of cocoon per liter, larval duration of fifth and total larval duration and crop by weight.

The present results reveal that, no hybrids appear heterosis over check parent for all traits under study. Hybrids of (H_3, H_6 and H_{15}) acquired better values than the imported hybrid for all characters except mortality percentage.

These are in coincidence with those found by Lakshmanan and Suresh Kumar (2012) [10] studied hybrid vigour in some 10 double hybrids. None of them are superior in all traits together.

3.3. Evaluation index for all hybrids

Evaluation index value for imported and fifteen local hybrids registered in figures 6, 7, 8, 9 and 10. The results reveal hybrids of (H_1, H_8 and H_{16}) were the worst hybrids. Looking at the average of evaluation index for all traits, it is appearing that hybrids of (H_3, H_7, H_6, H_{12}, H_5, H_4 and H_{15}) have higher average over than 50. So that the previous seven hybrids is better than imported one. Ghazy (2014) [6] evaluation index values revealed that eight hybrids were best from thirteen hybrids tested. Babu *et al.* (2002) [1] eighteen new bivoltine silkworm *B. mori* L. hybrids were evaluated using evaluation index equation. Only one hybrid combination is being the best among the 18 hybrids.

3.4. Subordinate function for all hybrids

Data in Table 3 showed subordinate function values of fifteen double local and imported Bulgarian hybrids. It is appear that, most of local double hybrids earned best results. Only hybrid of H_3 acquired better data for all traits as well as the cumulative subordinate function. H_1 and H_{16} hybrids earned lowest cumulative subordinate function values. Cumulative subordinate function ranged from 3.752 (H_1) up to the maximum value 16.013 of (H_3) which assigned first demotion. The remaining hybrids are allocated descending order. Similar results were recorded by Babu *et al*. (2002) [1] and Ghazy (2007) [5] evaluated some hybrids using subordinate function. The hybrid with the highest subordinate function value is assigned first rank.

3.5. Ranking of the hybrids

Ranking of fifteen local mulberry silkworm and imported hybrids were illustrated in Table 4 according to average of evaluation index and cumulative value of subordinate function. Hybrids acquired best data for average of evaluation index and cumulative subordinate function. Hybrids of H_1 and H_{16} have lowest of evaluation index value and cumulative subordinate function. Also, the order of the two previous hybrids was ranking the last order. Mostly, the best hybrids ranking the first order for evaluation index value and cumulative subordinate function together.

These results are in accordance with found by Singh *et al.* (2015) [13] subordinate function used to identifying the multivoltine breeds and multivoltine x bivoltine hybrids of the mulberry silkworm, *Bombyx mori* L. Among seventeen multivoltine x bivoltine hybrids, DNP $_1$x CSR $_2$ ranked first exhibiting maximum cumulative subordinate function indices values followed by DNP_1 x CSR_{17} exhibiting cumulative subordinate function indices values. Besides, seven multivoltine x bivoltine hybrids viz., DNP_3 x CSR_{17}, DNP_2 x CSR_{17}, DNP_3 x CSR_2, DNP_2 x NB_4D_2, DNP_2 x CSR_2, DNP_1 x NB_4D_2 and DNP_2 x CSR_2.

Table 1: Codes and methods of hybridization local double and single hybrids.

Double hybrid cods	Hybridization	Single hybrid cods	Hybridization
H $_1$	hy $_1$ X hy $_{13}$	hy $_1$	RBPch $_4$ X Z $_{111}$
H $_2$	hy $_2$ X hy $_3$	hy $_2$	RBPch $_4$ X I_2 PJ
H $_3$	hy $_2$ X hy $_4$	hy $_3$	O $_{323}$ X C $_{137}$
H $_4$	hy $_3$ X hy $_2$	hy $_4$	C $_{137}$ X O $_{323}$
H $_5$	hy $_4$ X hy $_2$	hy $_5$	H $_{155}$ X X $_{482}$
H $_6$	hy $_5$ X hy $_6$	hy $_6$	RBPch $_4$ X H $_{155}$
H $_7$	hy $_6$ X hy $_5$	hy $_7$	C $_{137}$ X K $_{462}$
H $_8$	hy $_7$ X hy $_8$	hy $_8$	J $_{325}$ X O $_{323}$
H $_9$	hy $_8$ X hy $_7$	hy $_9$	O $_{323}$ X H $_{155}$
H $_{10}$	hy $_9$ X hy $_{10}$	hy $_{10}$	H $_{155}$ X RBPch $_4$
H $_{11}$	hy $_{10}$ X hy $_9$	hy $_{11}$	RBPch $_4$ X O $_{323}$
H $_{12}$	hy $_{11}$ X hy $_{12}$	hy $_{12}$	O $_{323}$ X RBPch $_4$
H $_{13}$	hy $_{12}$ X hy $_{11}$	hy $_{13}$	O $_{323}$ X Z $_{111}$
H $_{14}$	hy $_1$ X hy $_{14}$	hy $_{14}$	Y $_{165}$ X O $_{323}$
H $_{15}$	hy $_{13}$ X hy $_{15}$	hy $_{15}$	H $_{155}$ X O $_{323}$

All data were analyzed using check parent value formula. As well as modified of evaluation index and subordinate function formulae (Ghazy, 2014) as follows:

Table 2: Performance of fifteen double local and imported Bulgarian hybrids during Spring season.

Character \ Hybrids	FCW	MCW	FCSW	MCSW	FPW	MPW	FCSR	MCSR	FSP	MSP
H $_1$	0.936	0.823	0.109	0.106	0.832	0.718	11.497	12.749	1.167	1.128
H $_2$	0.974	0.935	0.172	0.211	0.794	0.720	17.549	22.435	1.838	2.254
H $_3$	1.440	1.112	0.279	0.266	1.176	0.862	19.408	23.854	3.328	3.171
H $_4$	1.276	0.999	0.220	0.204	1.043	0.788	17.259	20.359	2.626	2.437
H $_5$	1.280	1.038	0.218	0.206	1.052	0.812	16.799	20.043	2.603	2.462
H $_6$	1.233	0.965	0.243	0.208	1.032	0.755	19.676	21.690	2.903	2.485
H $_7$	1.401	1.089	0.275	0.234	1.112	0.829	19.688	21.253	3.731	3.167
H $_8$	1.120	0.948	0.201	0.211	0.927	0.744	17.770	22.223	2.142	2.252
H $_9$	1.192	1.030	0.223	0.215	1.013	0.819	22.958	20.749	2.374	2.296
H $_{10}$	1.315	1.037	0.217	0.204	1.087	0.857	16.544	19.609	2.319	2.175
H $_{11}$	1.129	0.851	0.229	0.205	0.904	0.643	20.409	24.094	2.440	2.191
H $_{12}$	1.296	1.115	0.202	0.214	1.078	0.877	15.622	19.377	2.153	2.287
H $_{13}$	1.239	0.937	0.214	0.206	0.999	0.740	17.151	21.980	2.280	2.197
H $_{14}$	1.232	0.987	0.199	0.183	0.982	0.782	16.025	18.464	2.124	1.951
H $_{15}$	1.225	0.955	0.228	0.206	0.989	0.750	18.582	21.604	2.432	2.196
H $_{16}$	0.977	0.749	0.181	0.153	0.763	0.562	18.406	20.426	1.643	1.391
SD	0.146	0.102	0.040	0.034	0.116	0.082	2.517	2.612	0.611	0.512

Table 2: (Continued)

Character \ Hybrids	P%	CP	C/L	FD	LD	M%	C/No	C/W
H 1	93.000	61.500	150.400	9.000	36.000	9.800	6150.000	5756.605
H 2	92.000	77.000	139.400	9.375	35.375	18.667	7700.000	7501.597
H 3	100.000	86.286	142.400	8.375	36.375	8.750	8628.571	12428.306
H 4	97.000	68.182	132.800	8.000	35.416	31.500	6818.182	8698.409
H 5	94.000	70.000	132.800	8.375	35.375	24.500	7000.000	8960.933
H 6	98.000	86.500	138.400	8.375	35.000	10.850	8650.000	10668.910
H 7	99.000	71.667	136.800	7.000	34.375	28.000	7166.667	10038.112
H 8	98.000	71.500	175.200	9.375	37.000	1.050	7150.000	8010.383
H 9	99.000	55.051	135.000	9.375	36.375	0.700	5505.050	6564.387
H 10	91.000	58.571	140.000	9.375	36.000	34.500	5857.143	7703.510

H 11	96.000	77.966	144.800	9.375	36.375	8.050	7796.610	8804.972
H 12	96.000	86.286	136.600	9.000	36.375	14.000	8628.571	11183.203
H 13	96.000	75.000	151.200	9.375	37.000	10.500	7500.000	9289.250
H 14	100.000	72.632	145.600	9.000	36.375	1.750	7263.158	8947.969
H 15	100.000	78.000	140.000	9.375	36.375	18.900	7800.000	9551.880
H 16	98.000	78.000	168.000	11.000	38.375	2.450	7800.000	7623.460
SD	2.892	9.404	12.025	0.862	0.929	10.983	940.416	1709.477

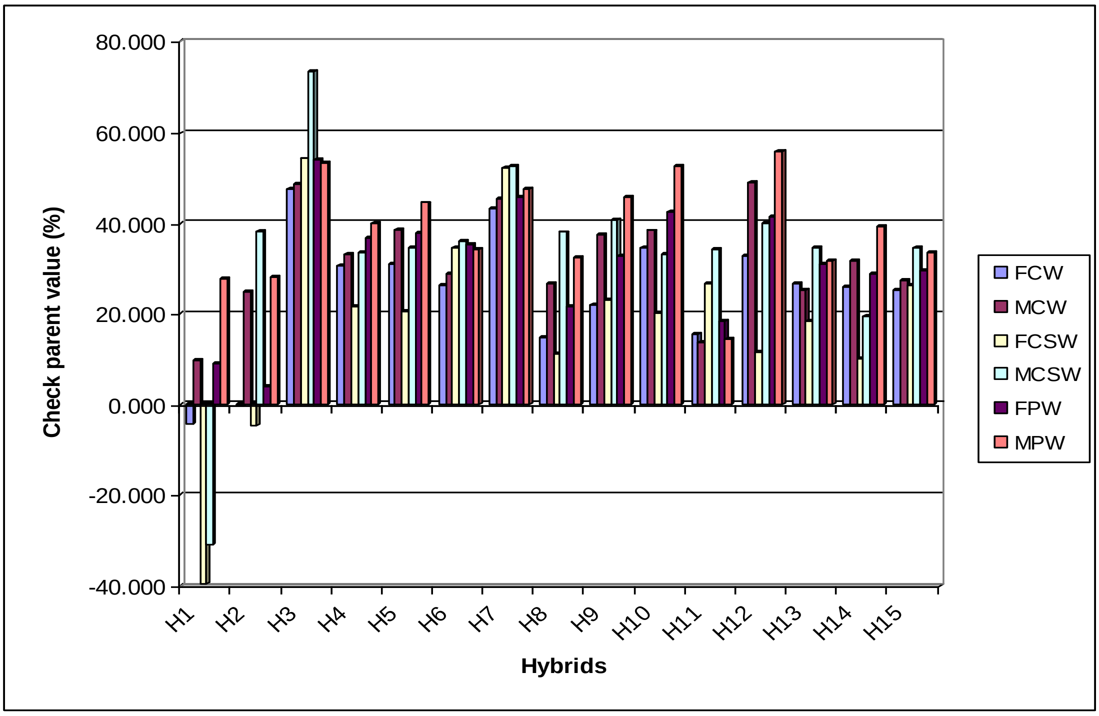

Fig 1: Check parent values for fresh cocoon, cocoon shell and pupal weights of fifteen local double hybrids.

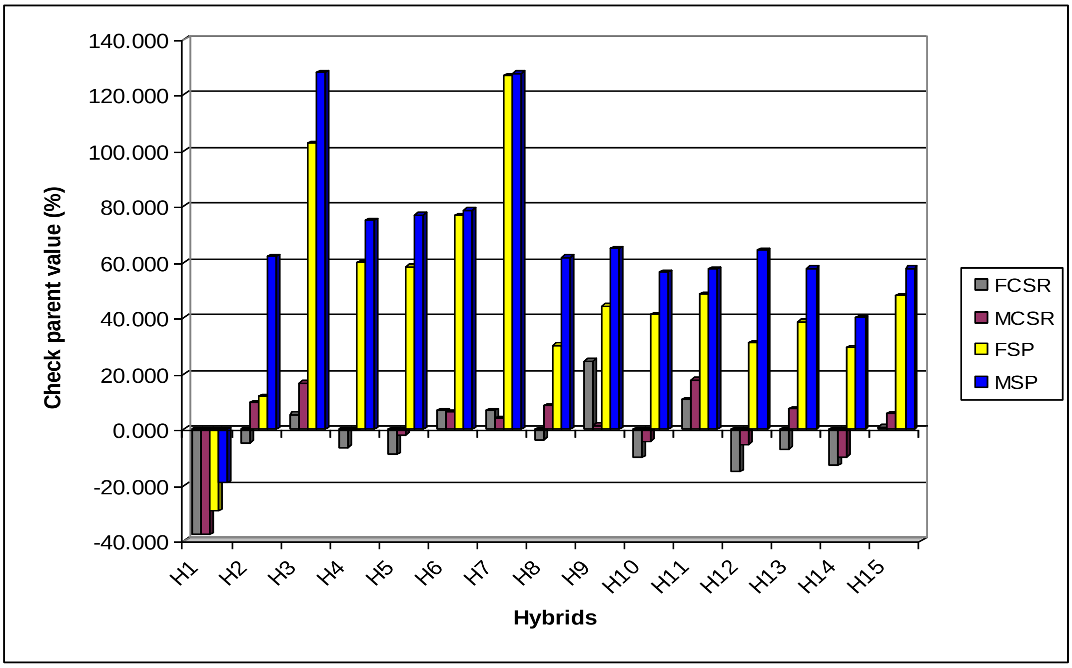

Fig. 2: Check parent values for cocoon shell ratio and silk productivity of fifteen local double hybrids.

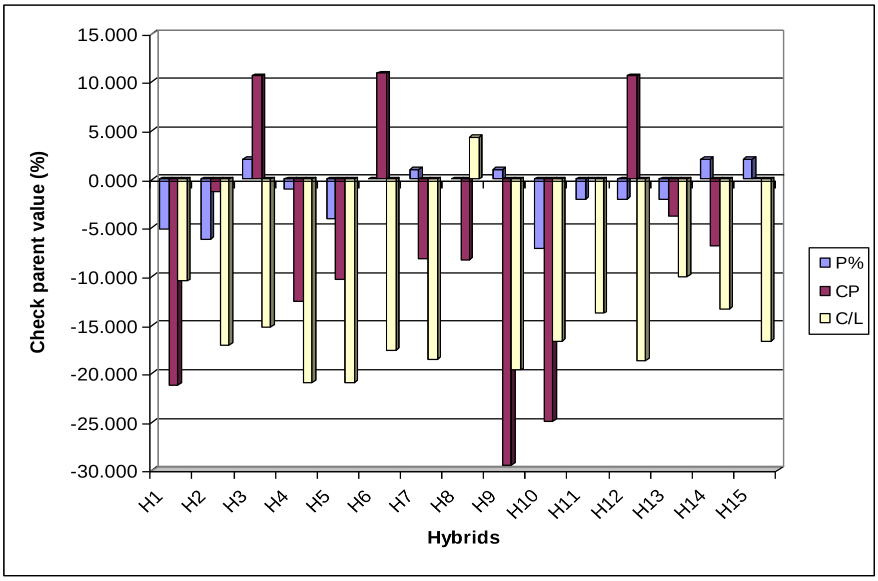

Fig.3: Check parent values for pupation ratio, cocooning percentage and No. of cocoon per liter of tested hybrids.

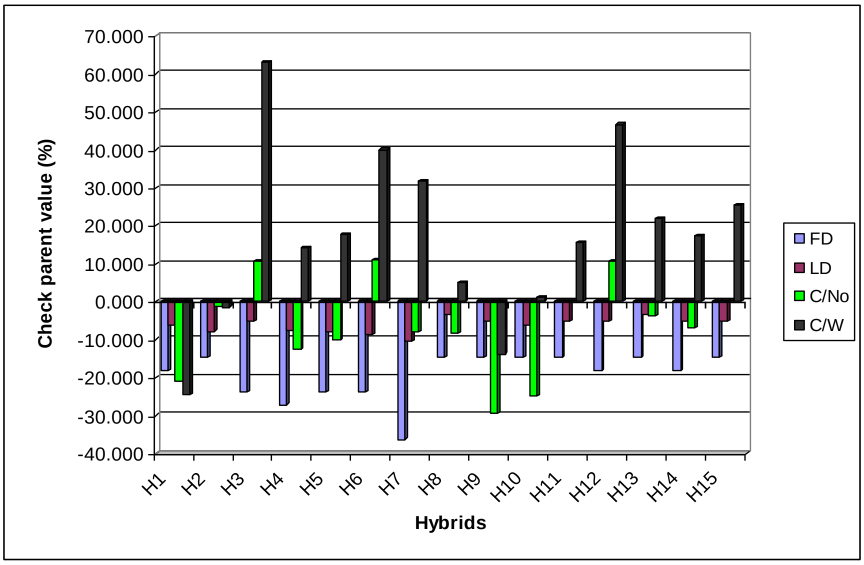

Fig 4: Check parent values for 5th duration, larval duration, crop by number and weight of tested hybrids.

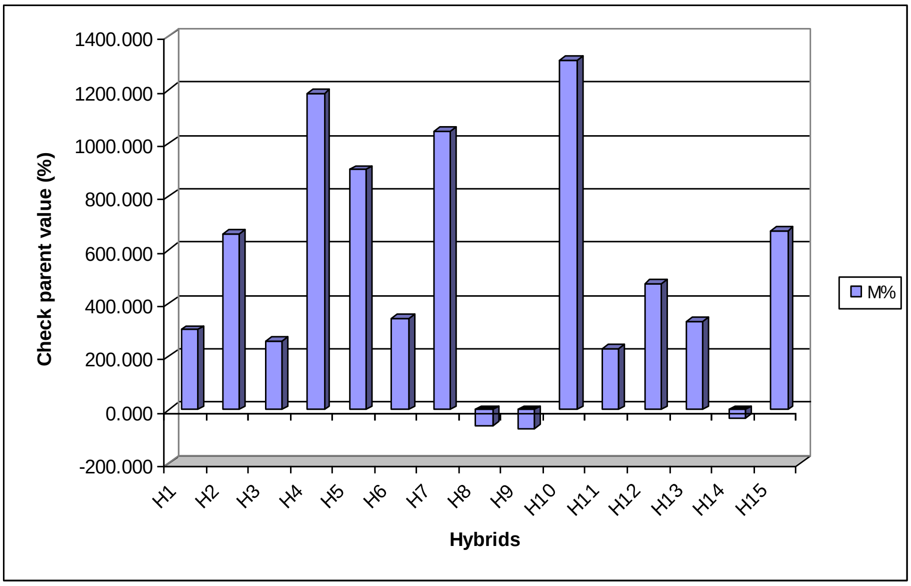

Fig 5: Check parent values for mortality percentage of hybrids.

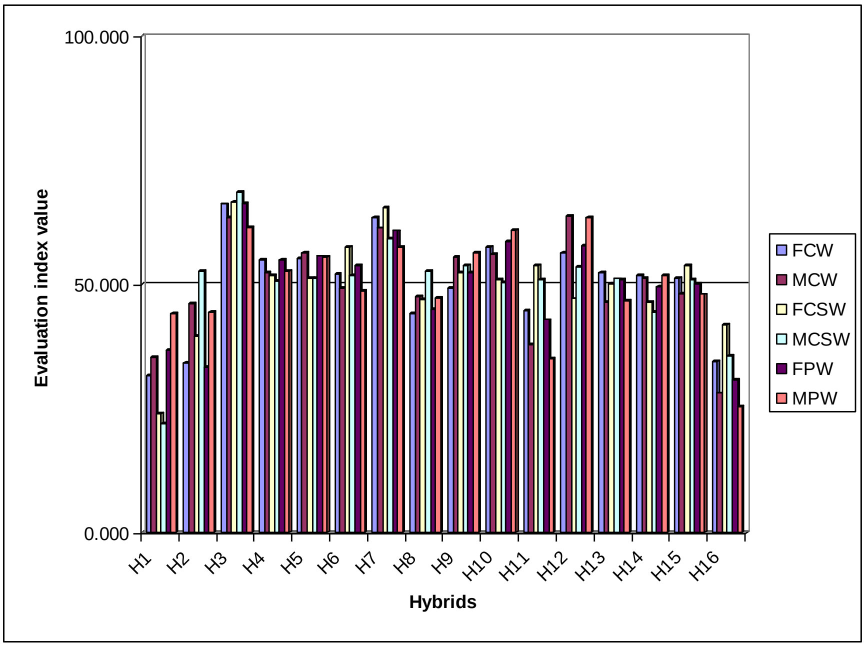

Fig 6: Evaluation index values of fresh cocoon, cocoon shell and pupal weights of fifteen local double hybrids.

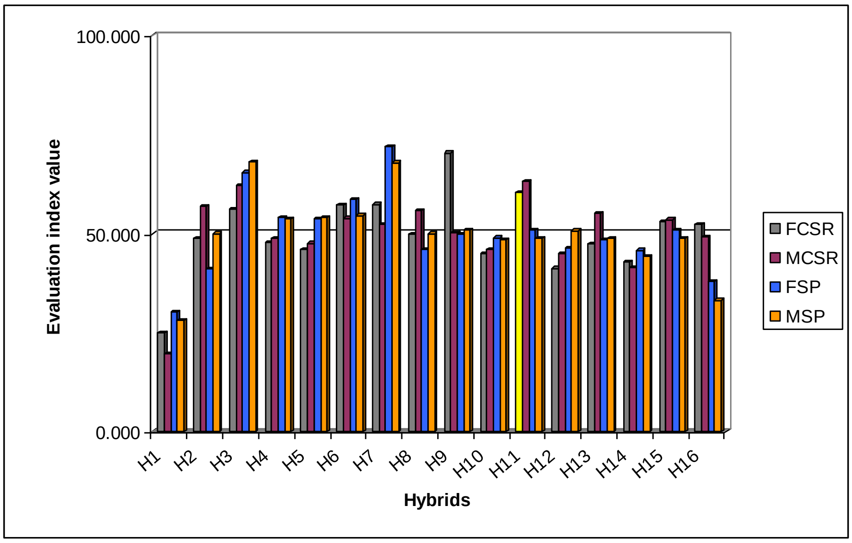

Fig 7: Evaluation index values for cocoon shell ratio and silk productivity of fifteen local double hybrids.

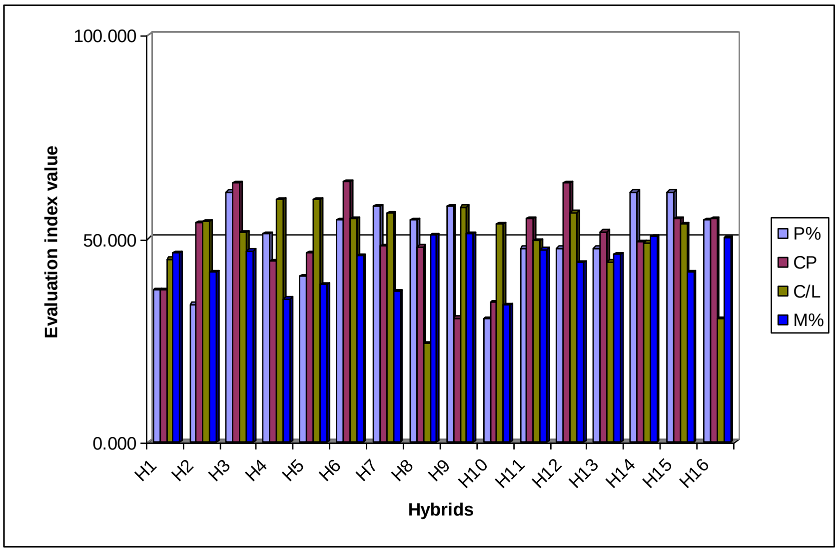

Fig 8: Evaluation index values for pupation ratio, cocooning percentage, number of cocoons per liter and mortality percentage of tested hybrids.

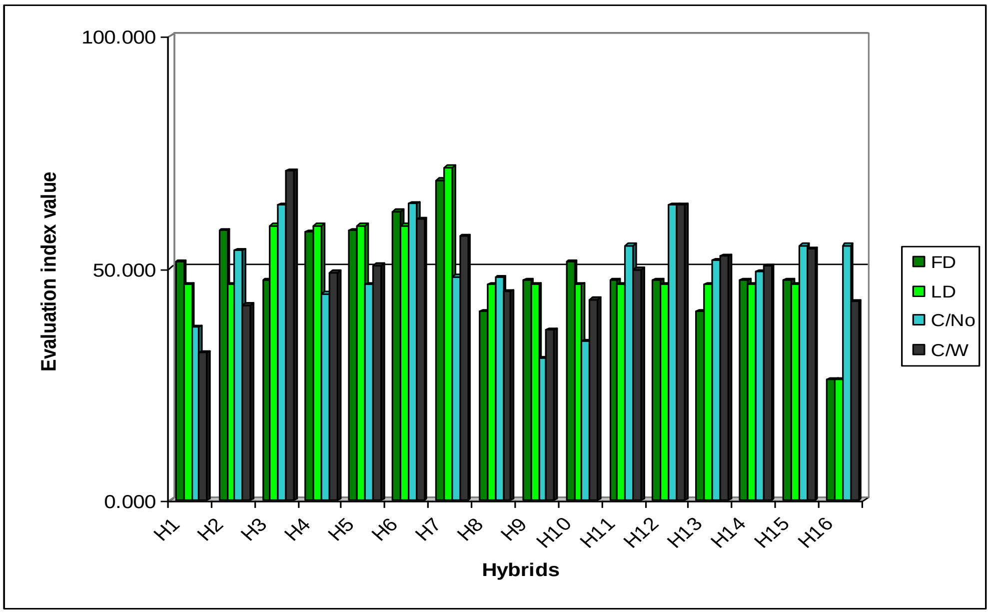

Fig 9: Evaluation index values for 5th duration, larval duration, crop by number and crop by weight of tested hybrids.

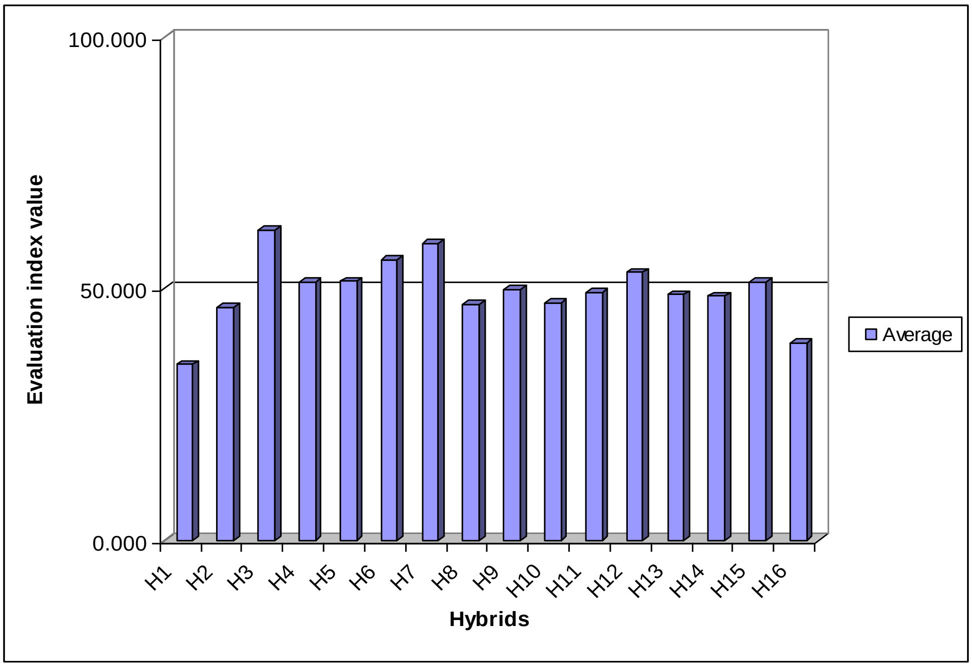

Fig 10: Average of evaluation index values for all characters under study.

Table 3: Subordinate function values of fifteen double local hybrids and imported Bulgarian hybrids.

Character\ Hybrids	FCW	MCW	FCSW	MCSW	FPW	MPW	FCSR	MCSR	FSP	MSP
H 1	0.000	0.202	0.000	0.000	0.167	0.494	0.000	0.000	0.000	0.000
H 2	0.076	0.506	0.371	0.660	0.074	0.502	0.528	0.854	0.261	0.551
H 3	1.000	0.992	1.000	1.000	1.000	0.953	0.690	0.979	0.843	1.000
H 4	0.674	0.681	0.653	0.615	0.678	0.717	0.503	0.671	0.569	0.641
H 5	0.682	0.787	0.642	0.628	0.701	0.795	0.463	0.643	0.560	0.653
H 6	0.590	0.589	0.790	0.641	0.652	0.611	0.714	0.788	0.677	0.664
H 7	0.921	0.929	0.979	0.800	0.845	0.848	0.715	0.750	1.000	0.998
H 8	0.365	0.542	0.540	0.660	0.398	0.577	0.547	0.835	0.380	0.550
H 9	0.508	0.766	0.668	0.685	0.606	0.815	1.000	0.705	0.471	0.572
H 10	0.752	0.785	0.638	0.614	0.784	0.936	0.440	0.605	0.449	0.512
H 11	0.383	0.278	0.705	0.623	0.342	0.257	0.778	1.000	0.496	0.520
H 12	0.714	1.000	0.546	0.680	0.763	1.000	0.360	0.584	0.385	0.567
H 13	0.600	0.514	0.616	0.627	0.571	0.565	0.493	0.814	0.434	0.523
H 14	0.587	0.648	0.530	0.483	0.531	0.699	0.395	0.504	0.373	0.403
H 15	0.572	0.563	0.701	0.626	0.549	0.596	0.618	0.781	0.494	0.523
H 16	0.082	0.000	0.421	0.296	0.000	0.000	0.603	0.677	0.186	0.129

Character \ Hybrids	P%	CP	C/L	FD	LD	M%	C/No.	C/W	cumulative
H_1	0.222	0.205	0.585	0.500	0.594	0.731	0.205	0.000	3.752
H_2	0.111	0.698	0.844	0.406	0.750	0.468	0.698	0.262	8.196
H_3	1.000	0.993	0.774	0.656	0.500	0.762	0.993	1.000	16.013
H_4	0.667	0.418	1.000	0.750	0.740	0.089	0.418	0.441	10.100
H_5	0.333	0.475	1.000	0.656	0.750	0.296	0.475	0.480	10.415
H_6	0.778	1.000	0.868	0.656	0.844	0.700	1.000	0.736	13.112
H_7	0.889	0.528	0.219	0.364	0.104	0.188	0.528	0.642	11.613
H_8	0.778	0.523	0.000	0.406	0.344	0.990	0.523	0.338	9.413
H_9	0.889	0.000	0.948	0.406	0.500	1.000	0.000	0.121	10.787
H_{10}	0.000	0.112	0.830	0.406	0.594	0.000	0.112	0.292	7.948
H_{11}	0.556	0.729	0.717	0.406	0.500	0.783	0.729	0.457	10.158
H_{12}	0.556	0.993	0.910	0.500	0.500	0.607	0.993	0.813	12.188
H_{13}	0.556	0.634	0.566	0.406	0.344	0.710	0.634	0.529	9.962
H_{14}	1.000	0.559	0.698	0.500	0.500	0.969	0.559	0.478	10.511
H_{15}	1.000	0.730	0.830	0.406	0.500	0.462	0.730	0.569	10.815
H_{16}	0.778	0.730	0.170	0.000	0.000	0.948	0.730	0.280	6.101

Table 4: Ranking of fifteen local mulberry silkworm and imported hybrids.

serial	Hybrids	Evaluation index average	Cumulative subordinate function
1	H_3	61.643	16.013
2	H_6	55.697	13.112
3	H_{12}	53.265	12.188
4	H_7	59.046	11.613
5	H_{15}	51.315	10.815
6	H_9	49.966	10.787
7	H_{14}	48.545	10.511
8	H_5	51.459	10.415
9	H_{11}	49.265	10.158
10	H_4	51.225	10.100
11	H_{13}	48.818	9.962
12	H_8	46.852	9.413
13	H_2	46.199	8.196
14	H_{10}	47.259	7.948
15	H_{16}	39.340	6.101
16	H_1	34.965	3.752

4. Conclusion

From the previous results it could be concluded that, most of local double hybrids have superior over the imported one. This may be there were adaptation cause with the local lines for the climatic changes. Although there was acute changing in Egyptian conditions there were some promising double hybrids can be exploitation in commercial scale. So that, the breeding program must be have continuous to create varieties suitable for the fluctuations in climatic conditions.

5. Acknowledgement

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6. References

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