temperature, low food quality, relatively higher economic traits, with the potential for increased cocoon production (Suresh Kumar *et al*., 2011).

A significant impact of silkworm hybrids through the exploitation of hybrid vigour where introduce through several scientists across the sericulture countries to increased quantitative and qualitative silk productivity besides crop stability on a commercial scale and succeeded in the development bivoltine silkworm hybrids (Harada, 1961; Mano *et al*. 1982; He *et al*. 1991; Chen *et al*., 1994; Basavaraja *et al*. 1995; Rajalakshmi *et al*. 1998; Datta *et al*. 2000; Sudhakara Rao *et al*. 2001; Suresh Kumar *et al*. 2004 , Jalali *et al*. 2011; Khan, 2015 and Ghazy *et al*. 2017).

Heterosis estimation for mulberry silkworm, *Bombyx mori* L., of some local hybrids will be adopted. Evaluate the hybrid vigour over two imported hybrids. Also, this study aims to develop hybrids in Egypt.

MATERIALS AND METHODS

Six silkworm races *Bombyx mori* L. were used for hybridization. It is obtained from the Sericulture Research Department – Plant Protection Research Institute – Agricultural Research Center. The races are $RBPJ_3$, $RBPch_4$, L_{252}, O_{111}, I_{214} and G_{155}. The hybridization made as follows (Table 1):

Table.1. Hybridization method of local hybrids and its codes.

No.	hybrid	Code
1	L_{252} X $RBPch_4$	HY A
2	$RBPch_4$ X L_{252}	HY B
3	G_{155} X O_{111}	HY X
4	O_{111} X G_{155}	HY D
5	I_{214} X $RBPj_3$	HY F

In addition two imported hybrids from Bulgaria are $G_2XK_2XH_1XKK$ and $H_1XkkXV_2XG_2$ which coded as G_1 and G_2, respectively.

Three replicates of each hybrid were reared. Each replicate contained 500 larvae. Mulberry leaves of *Morus alba* var Kokoso-27 were used for feeding larvae of a silkworm. Chopped leaves were offered during young instars. Whole leaves and shoots used for feeding fourth and fifth instar, respectively. Collapsible frames applied for mountage. During young silkworm wet foam used for adjusted the humidity and polythene sheets for bottom and cover of rearing trays (Ghazy, 2008). Temperature and humidity inside rearing room recorded. Average of temperature was 28.2 ± 2 and 66.5 ± 2 %for humidity percentage.

Data were registered for the following characters: cocoon weight (CW), cocoon shell weight (CSW), pupal weight (PW), cocoon shell ratio (CSR), silk productivity (SP) for females and males. fifth instar duration (Fd), total larval duration (LD), mortality percentage (MP), number of cocoon per liter (C/L), cocooning percentage (CP), pupation ratio (PR), cocoon crop by number (Crop/No) and weight (Crop/W), fecundity (Fecund) and fertility (Fertili).

Cocoon shell ratio for each entry was calculated according to Tanaka (1964) as follows:

$$\textbf{Cocoon shell ratio (\%)} = \frac{\text{cocoon shell weight}}{\text{fresh cocoon weight}} \text{ x100}$$

Silk productivity was estimated by using formula of Iyengar *et al*. (1983):

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

Pupation ratio was calculated according to the following formulae of LEA (1996):

$$\textbf{Pupation ratio (\%)} = \frac{\text{Number of health pupae}}{\text{Corrected basic number of examined}}$$

The formulae of estimating heterosis over better and mid parent values:
Heterosis was estimated by using the following formulae of (Rao *et al*. 2002):

1- $$\textbf{Heterosis over better parent value (BPV)} = \frac{\bar{F}_1 - BPV}{BPV} X100$$

Where: $\bar{F}_1$: Mean of hybrid

2- $$\textbf{Heterosis over mid parent value (MPV)} = \frac{\bar{F}_1 - MPV}{MPV} X100$$

BPV: The best value of the parents involved in the hybridization.
MPV: The average value of the parents involved in the hybridization.

3- The formula of heterosis over check parent value:
Heterosis was calculated according to the formula of Singh *et al*. (2002) as follows:

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

Where CPV: Check Parent Value
Modified of evaluation index and Subordinate function were calculated According to Ghazy (2014) as follow:
Evaluation index (EI) = ((A – B) / C × 10) + 50 for Positive traits
Evaluation index (EI) = 50 - ((A – B) / C × 10) for negative traits
$X_U = (X_I - X_{worst}) / (X_{best} - X_{worst})$
Where X_U = Subordinate Function, Xi = Measurement of the character of a tested genotype, X worst = the worst value of this character among all the tested genotypes, Xbest = the best value of this character among all the tested genotypes.

RESULTS AND DISCUSSION

Performance of Parental Races, Local and Imported Hybrids:

Mean performance of five local hybrids and two imported hybrids and six local races of silkworm *Bombyx mori* L. found in Table 2.
The performance of hybrids HY A, HY B and HY X are better than the parental races for CW, CSW, PW, SP for females and males. Also the previous hybrids are the best results for MP, C/L, fecund characters.
The performance of hybrid HY A is best than the imported hybrid G_1 for CW, CSW, PW, CSR, SP for females and males. In addition, FD, LD, C/L, CP, Crop/No, Crop/W, Fecund and fertili were superior. Moreover, the same local hybrid is better than the imported hybrid G_2 for CW, CSW, PW, CSR, C/L, CP, PR, Crop/No, Crop/W, fecund and fertili characters.

Table. 2. Performance of some local hybrids and two imported hybrids and six of local races of silkworm *Bombyx mori* L.

Character / Hybrids	CW (g)		CSW (g)		PW (g)		CSR (%)		SP (cg/day)	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
HY A	2.211	2.012	0.418	0.409	1.723	1.545	19.101	20.919	5.221	5.112
HY B	2.188	2.037	0.418	0.411	1.708	1.563	19.261	20.726	4.247	4.107
HY X	1.967	1.775	0.369	0.351	1.537	1.362	18.975	20.039	3.685	3.511
HY D	1.713	1.705	0.324	0.329	1.325	1.314	18.965	19.803	4.049	4.112
HY F	1.700	1.500	0.297	0.285	1.331	1.153	17.388	19.270	3.707	3.563
G_1	2.132	1.995	0.392	0.414	1.671	1.520	18.431	20.794	4.896	5.171
G_2	2.164	2.010	0.411	0.396	1.683	1.555	19.167	20.434	5.872	5.652
$RBPJ_3$	1.733	1.437	0.314	0.342	1.358	1.033	18.015	23.704	3.565	3.886
$RBPch_4$	1.705	1.335	0.309	0.256	1.334	1.017	18.115	19.070	3.509	2.913
L_{252}	1.367	1.117	0.227	0.214	1.077	0.843	16.550	18.999	2.840	2.674
O_{111}	1.310	1.092	0.214	0.202	1.034	0.827	16.350	18.526	2.433	2.300
I_{214}	1.452	1.229	0.248	0.256	1.143	0.912	16.966	20.864	3.098	3.197
G_{155}	1.247	1.081	0.206	0.214	0.979	1.545	16.497	20.919	2.288	5.112
SD	0.348	0.378	0.078	0.080	0.268	0.301	1.109	1.316	1.061	1.081

Table.2. (Continued)

Character / hybrid	Fd	LD	MP	C/L	CP	PR	Crop/No	Crop/w	Fecund	Fertili
HY A	8.000	28.000	15.000	105.040	93.000	99.000	9300.000	19637.384	498.200	97.593
HY B	9.000	29.000	16.000	105.000	94.761	100.000	9476.130	19853.377	497.200	98.467
HY X	10.000	29.000	16.000	128.800	71.428	98.000	7140.000	13362.010	416.600	90.284
HY D	8.000	27.000	14.000	119.840	73.000	98.000	7300.000	12474.459	525.600	80.531
HY F	9.000	28.000	19.000	114.240	75.400	97.000	7540.000	12062.975	452.200	94.604
G_1	8.000	28.000	13.000	120.400	89.000	100.000	8900.000	18365.862	413.600	95.393
G_2	7.000	27.000	11.000	105.280	75.400	90.000	7540.000	15736.534	435.333	97.631
$RBPJ_3$	8.800	30.000	18.000	150.267	82.979	100.000	8297.900	12730.389	392.333	97.429
$RBPch_4$	8.800	29.800	16.667	154.933	86.420	88.000	8641.900	13575.215	411.000	97.080
L_{252}	9.000	29.000	20.571	173.600	88.571	99.000	8857.100	10634.897	430.000	95.581
O_{111}	9.800	29.000	24.000	211.867	75.800	98.000	7580.000	9102.595	406.667	92.176
I_{214}	9.000	30.000	29.474	166.133	70.526	99.000	7052.600	9456.267	405.000	87.901
G_{155}	9.000	31.000	20.000	174.440	80.000	96.000	8000.000	9312.960	436.000	97.477
SD	0.802	1.200	4.898	33.808	8.383	3.796	838.543	3784.008	41.800	5.163

Evaluation of Heterosis:

For cocoon weight (CW), cocoon shell weight (CSW), pupal weight (PW), cocoon shell ratio (CSR), silk productivity (SP) for females and males. Pupation ratio (PR), cocooning percentage (CP), Fecundity (Fecund), Fertility (Fertili), cocoon crop by number (Crop/No) and weight (Crop/W) positive hybrid vigour is desirable. While negative hybrid vigour is required for mortality percentage (MP), fifth instar duration (Fd), total larval duration (LD), number of cocoons per liter (C/L).

1-Heterosis Over Mid Parent Value:

Figures 1- 3 illustrated the hybrid vigour over mid parent value for the fifteen characters under investigation.

CW, CSW, PW, CSR and SP showed positive heterosis over mid parent value for females and males except female CSR and male of CSW& CSR for hybrid HY F (Figs 1&2).

C/L, LD and MP represented negative hybrid vigour for all hybrids under study. Hybrids of HY B, HY X and HY F acquired undesirable positive hybrid vigour for Fd trait. All hybrids have positive heterosis of pupation ratio except that of HY F. Regarding to cocoon percentage and cocoon crop by number hybrids of HY A and B have positive hybrid vigour. Only hybrid HY X has negative hterosios for fecundity percentage trait, while HY X and HY D for fertility percentage character. All hybrids have positive heterosis for cocoon crop by weight traits (Fig.3).

There isn't any hybrid earned best hybrid vigour over mid parent value for all traits together. HY A hybrid has the best heterosis for most characters under study.

The same results were obtained by Sharma and Bali (2019) evaluated six parents and thirty-one hybrid combinations. Different hybrids combinations exhibited significant and desirable heterotic estimates at egg, larval, cocoon and post cocoon stage. No single hybrid is better for all characters together over mid parent value.

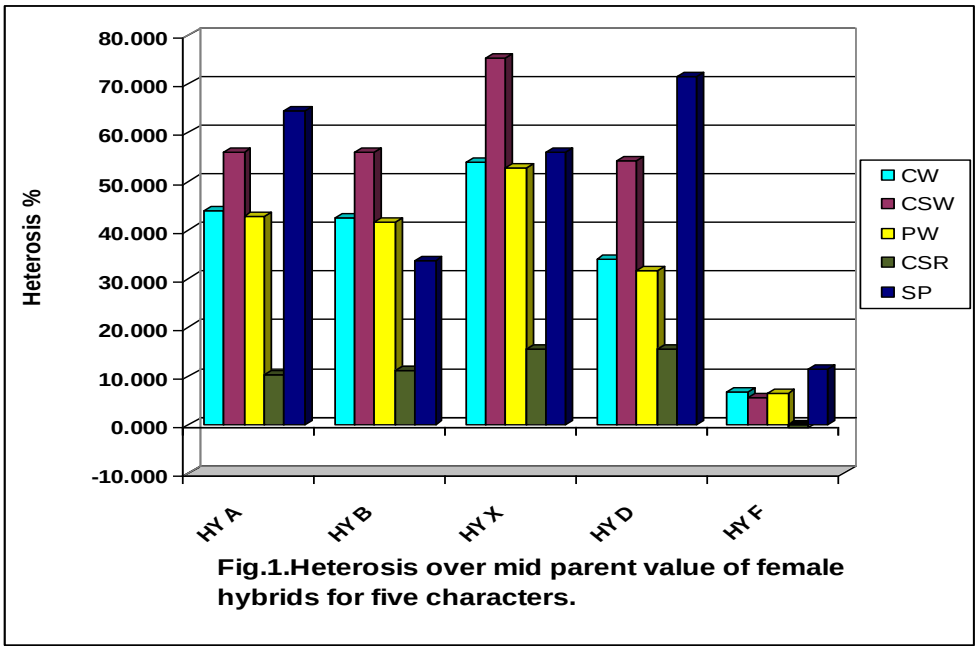

Fig.1.Heterosis over mid parent value of female hybrids for five characters.

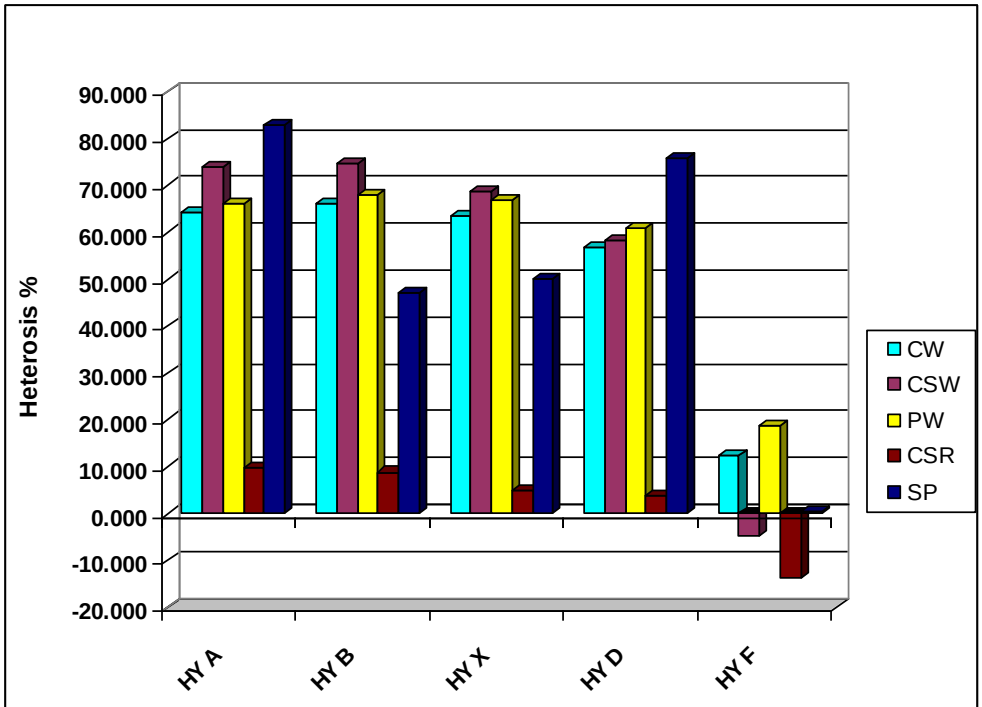

Fig.2. Heterosis over mid parent value of male hybrids for five characters.

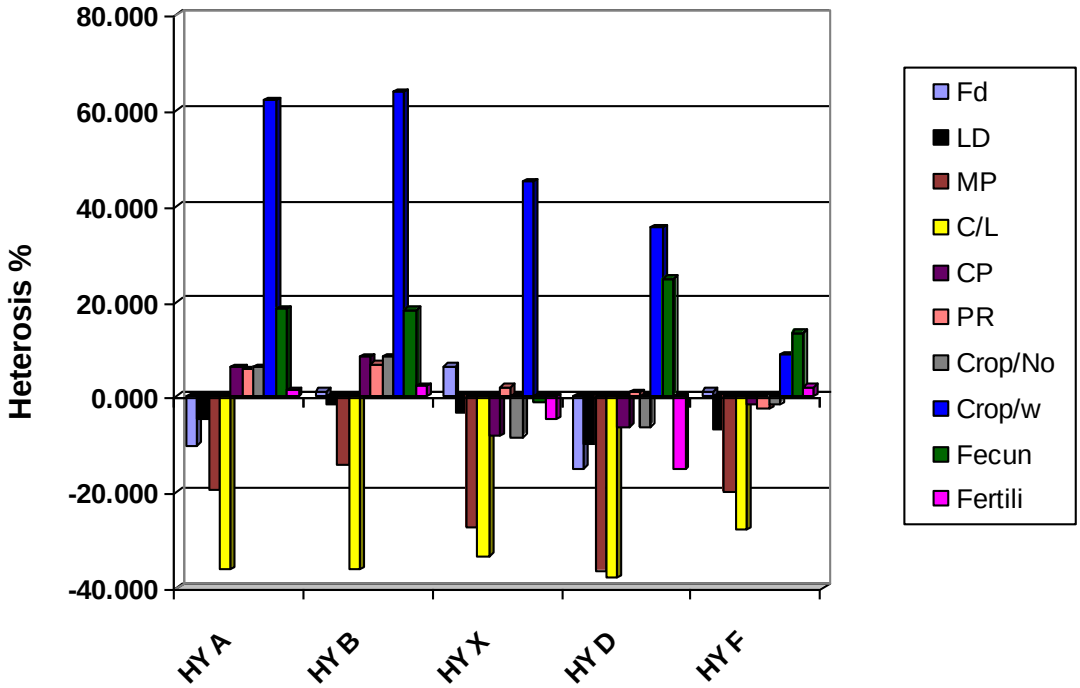

Fig.3. Heterosis over mid parent value of local hybrids for ten characters.

2-Hybrid Vigour Over Better Parent Value:

Heterosis over better parent value clarified in Figures 4-6 for previous traits. Females and males of all hybrids except HY F have the best hybrid vigour over better parent value for characters of cocoon weight, cocoon shell weight, pupal weight, cocoon shell ratio and silk productivity (Figs.4&5).

Best hybrid vigour over better parent value was detected for C/L, LD and MP for all hybrids except HY F for MP character. Only HY A and D have better heterosis for Fd traits. Only one hybrid (HY F) has the worst hybrid vigour for PR and Crop/W traits. About CP and Crop/No all hybrids have negative hybrid vigour over better parent value except those of HY A and HY B. Hybrids of HY A and HY D acquired the best heterosis for Fd trait. All hybrids have the best heterosis for fecundity character. Hybrids of HY A and B earned the best hybrid vigour for fertility character (Fig.6).

From the previous results, it appears that there are no hybrid has better hybrid vigour over better parent value for all characters together. Generally, Hybrid of HY A is better than others.

These results are coincidence with those found by Ghazy and Fouda (2006) they evaluated four simple hybrids. Heterosis over better parent value was registered for six characters. There is no superior hybrid in all traits together.

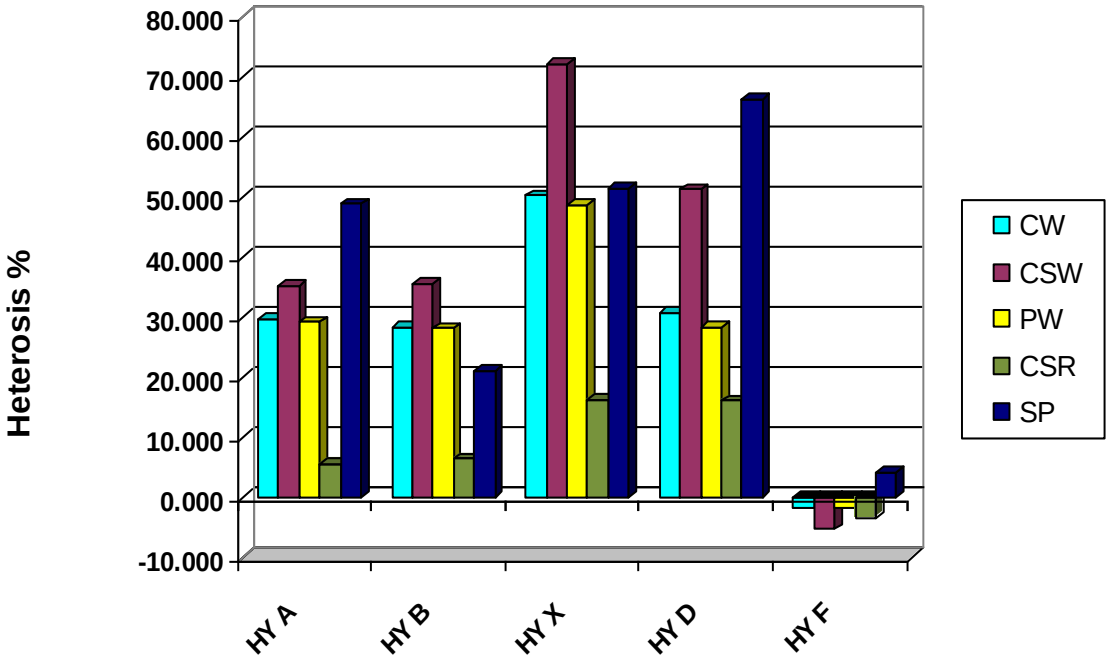

Fig.4. Heterosis over better parent value of female hybrids for five traits.

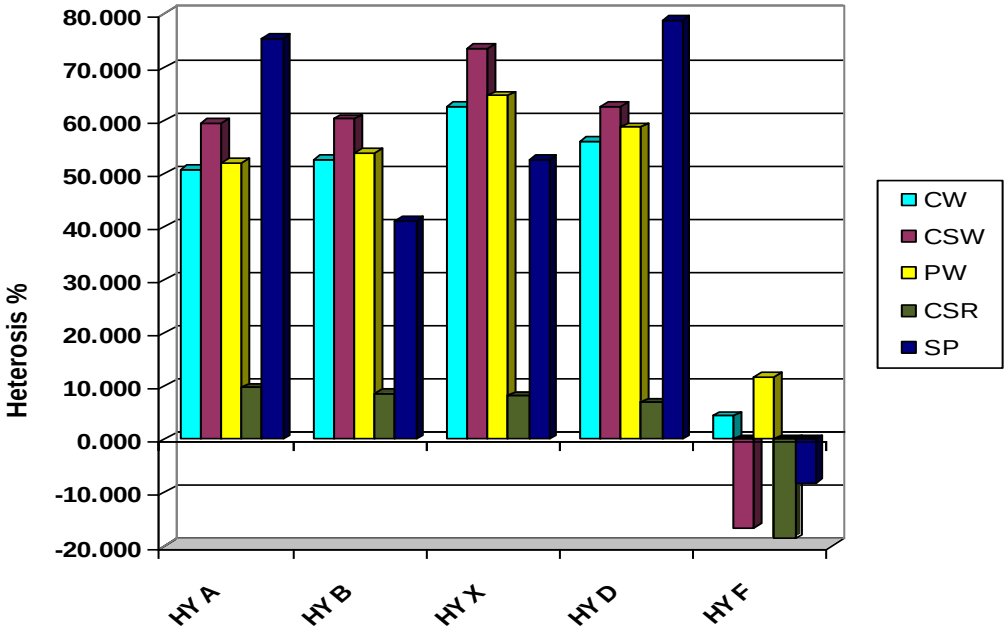

Fig.5. Heterosis over better parent value of male hybrids for five traits.

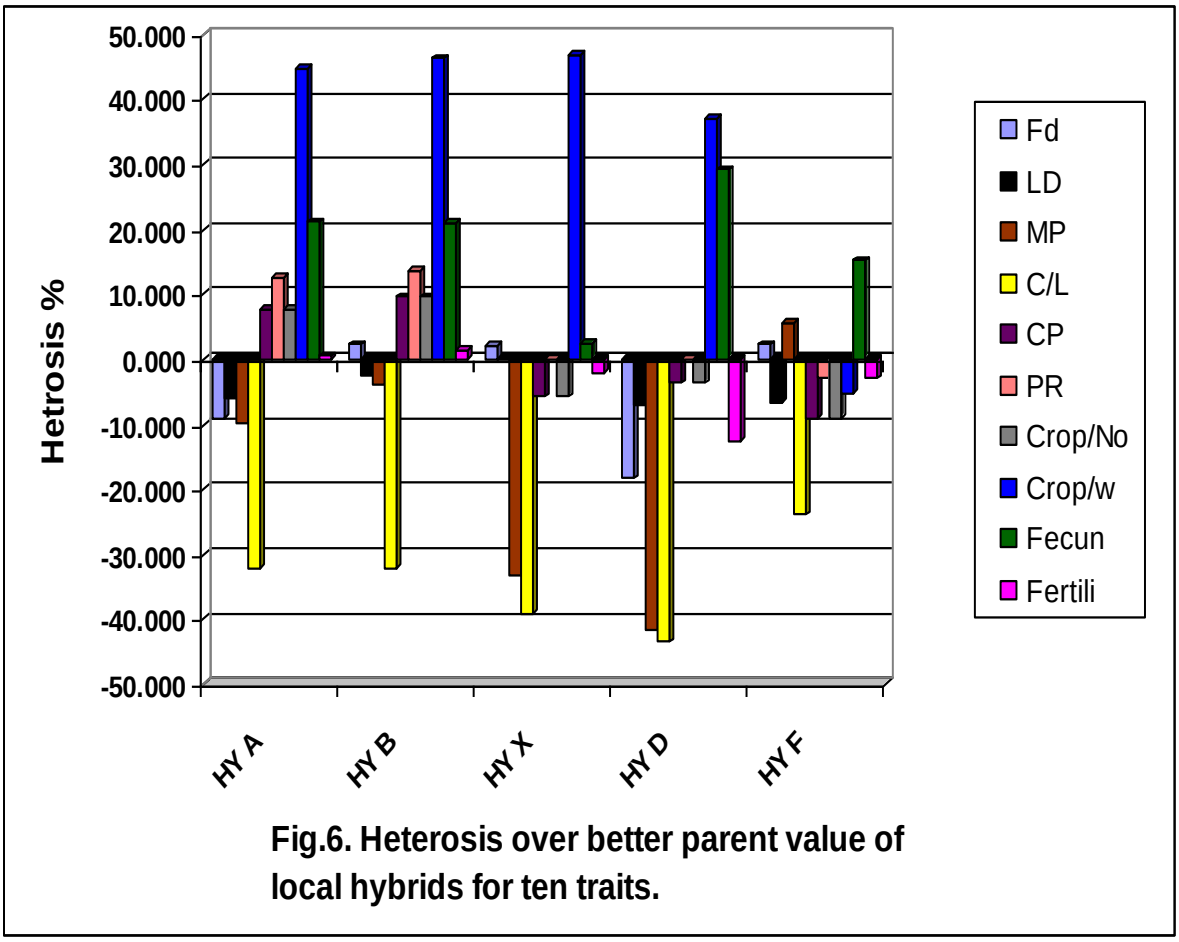

Fig.6. Heterosis over better parent value of local hybrids for ten traits.

3-Hybrid Vigor Over Check Parent Value:

Two imported hybrids from Bulgaria G_1 and G_2 used as check parents.

3-1 Check parent G1:

Hybrid vigour over check parent G_1 is founded in Figures 7-9.

Fig. 7 explained the hybrid vigour over check parent G_1 of five traits for females. Positive heterosis was detected for the female of HY A and HY B except for SP of HY B. Males of HY A showed hybrid vigour for CW, PW and CSR (Fig. 8).

There isn't any hybrid represent heterosis for Fd, LD and MP except HY D for larvae duration. Hybrid vigour over check parent value (G_1) appeared for all hybrids of C/L and PR except HY X for C/L and HY B for PR. Hybrids of HYA and HY B exhibit heterosis for CP, Crop/No, Crop/W and Fertili characters. All hybrids exposed hybrid vigour for Fecund trait.

Generally, HY A exhibited hybrid vigour over check parent value (G_1) of most characters understudy, this hybrid is promising and can be used for commercial production.

These results are in agreement with those found by Ghazy (2007) and who manifested hybrid vigour over check parent value. Some hybrids are promising which can be used for commercial production.

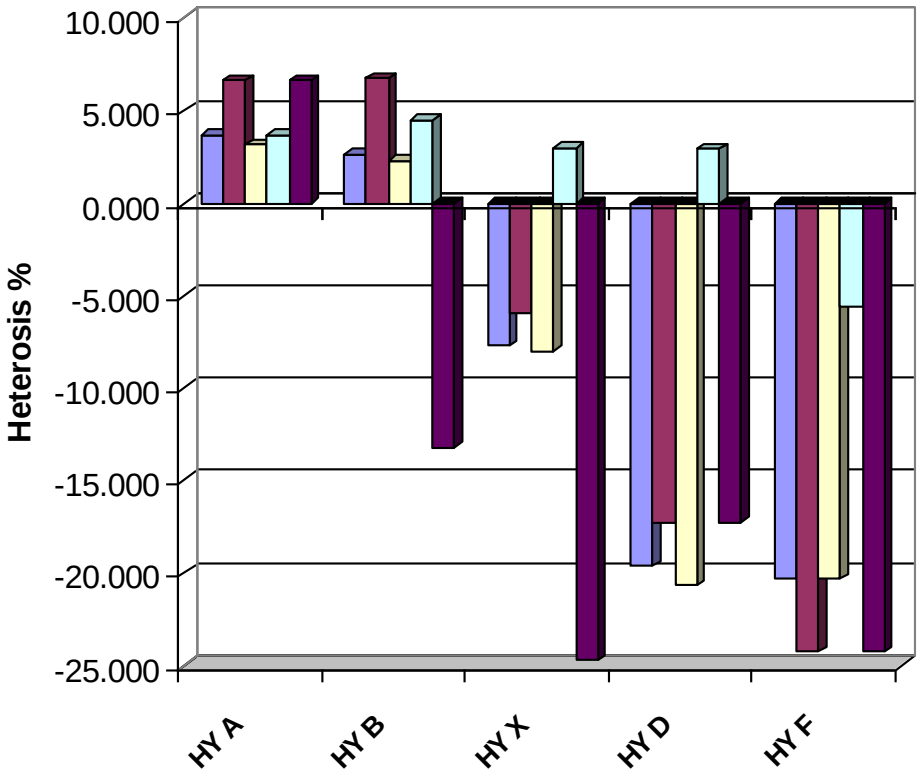

Fig.7. Heterosis over check parent (G_1) value of female hybrids for five traits.

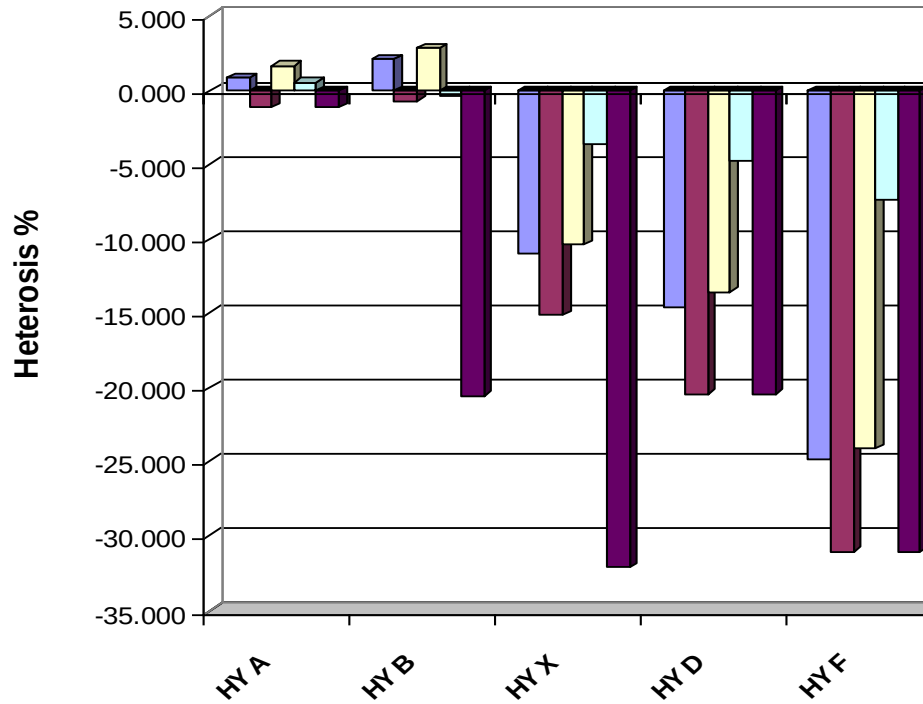

Fig.8. Heterosis over check parent (G_1) value of male hybrids for five traits.

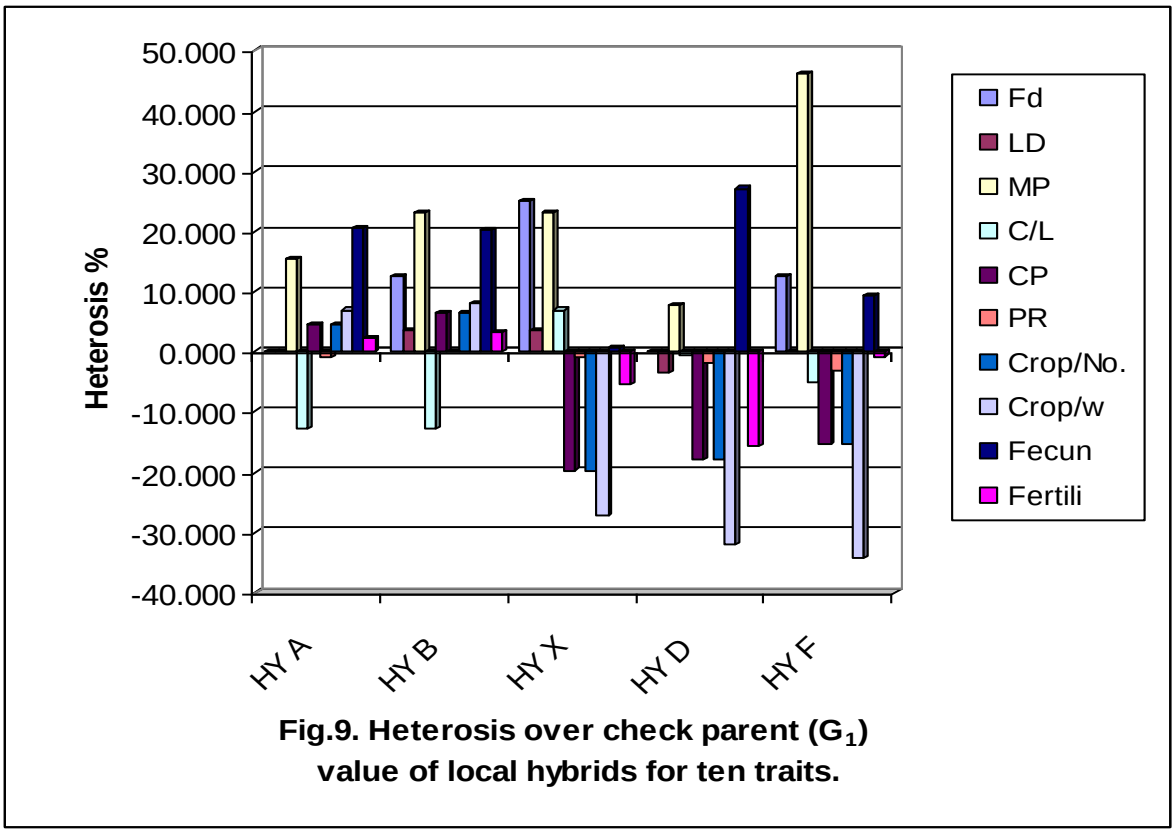

Fig.9. Heterosis over check parent (G_1) value of local hybrids for ten traits.

3-2 Check parent G_2:

Data in Figures 10-12 displayed the heterosis over check parent (G_2) for all characters under investigation.

Female of HY B has hybrid vigour for four characters and HY A for three traits. About male HY B submitted hybrid vigour for the same character as a female. And HY A male has heterosis for three characters (Figs. 10&11).

No hybrid showed hybrid vigour of Fd, LD and MP over check parent value (G_2). HY A and HY B represent hybrid vigour for C/L, CP, Crop/No and Crop/W characters. Heterosis was observed for four hybrids of PR, three hybrids for a fecund trait. Only a hybrid of HY B showed hybrid vigour for Fertili character.

Hybrids of HY A and HY B represent hybrid vigour over check parent (G_2) for most characters. There are promising hybrids that can be exploited commercially.

These results are contributed to the findings of Ghazy (2012) who estimation the hybrid vigour over check parent value for fourteen local hybrids. Only, one hybrid is promising for most characters.

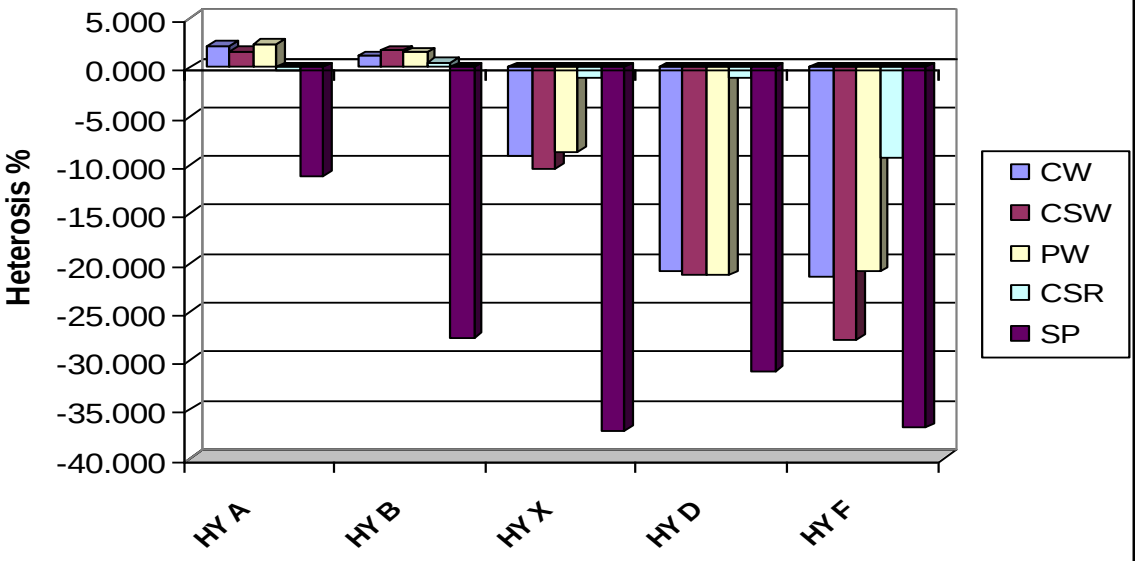

Fig.10. Heterosis over check parent (G_2) value of female hybrids for five traits

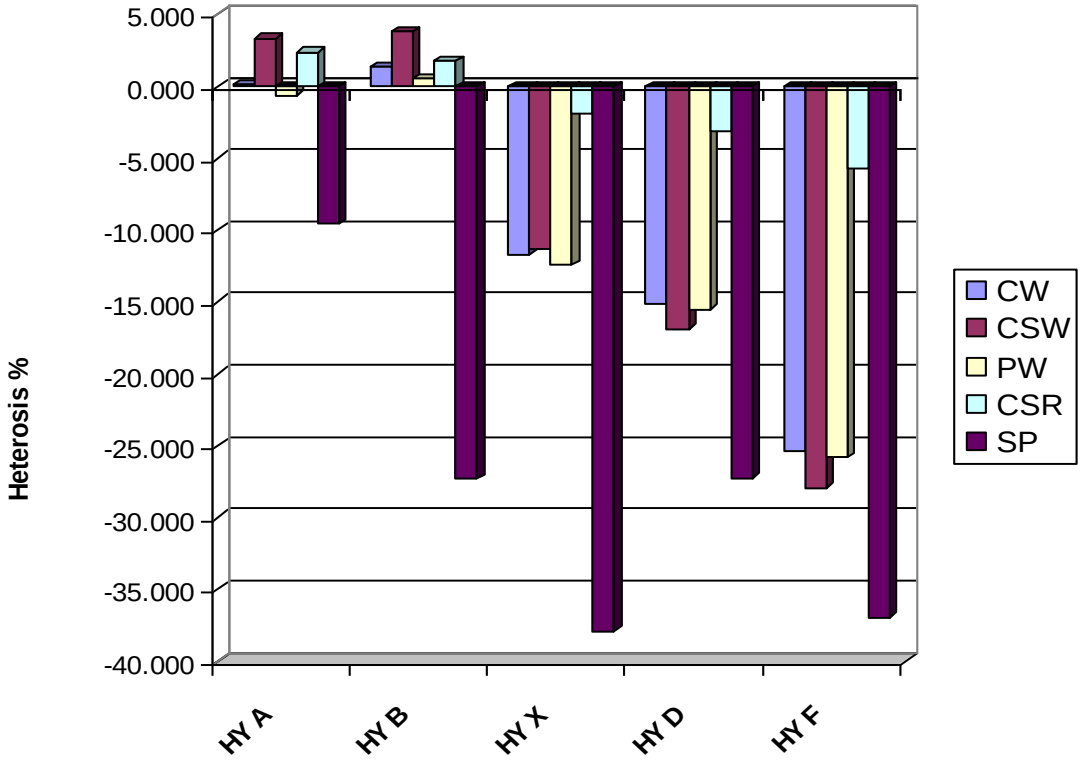

Fig.11. Heterosis over check parent (G_2) value of male hybrids for five traits.

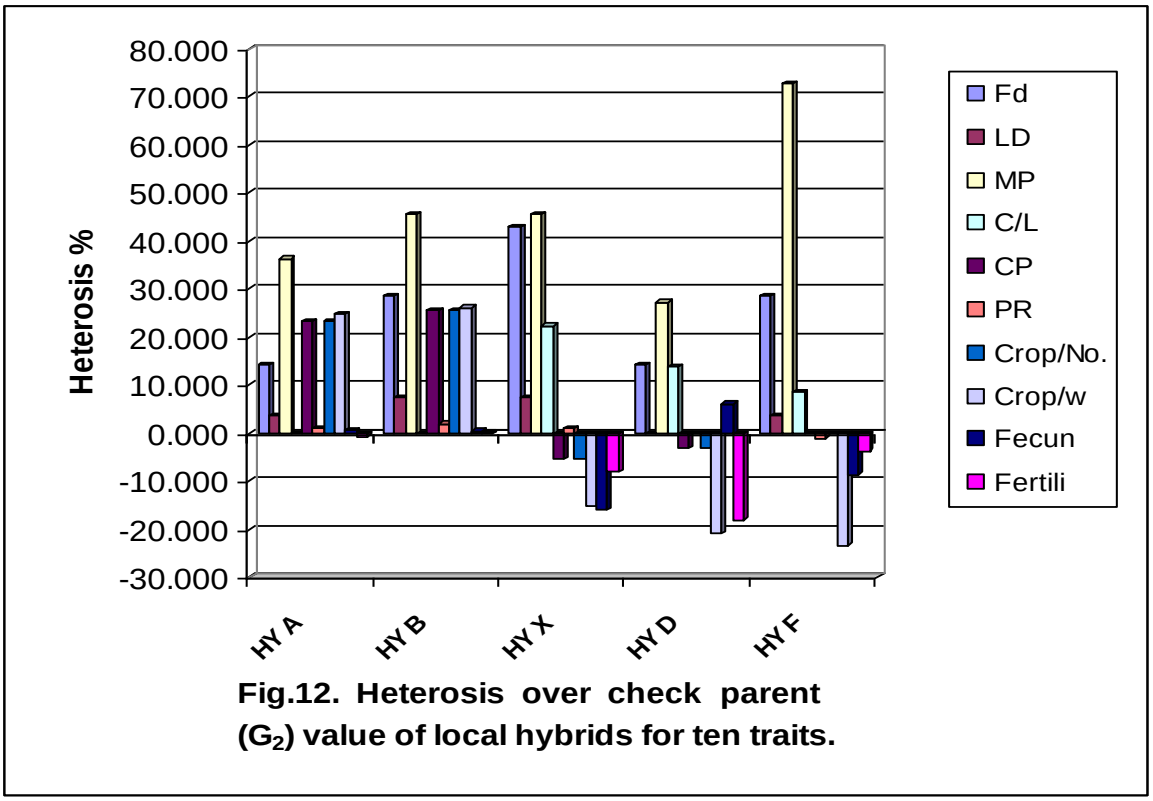

Fig.12. Heterosis over check parent (G_2) value of local hybrids for ten traits.

4-Evaluation Index Value:

Evaluation index values were found in Figures 13-16 for all traits under investigation. Values of evaluation index of female and male for cocoon weight (CW), cocoon shell weight (CSW), pupal weight (PW), cocoon shell ratio (CSR), silk productivity (SP) represented in Figures.13 &14. HY A and G_2 have valued over 50 for all previous characters. And HY B and G_1 have higher values than 50 for all traits except those of SP for HY B and CSR for G_1.

Values of pupation ratio (PR), cocooning percentage (CP), Fecundity (Fecund), Fertility (Fertili), cocoon crop by number (Crop/No) and weight (Crop/W) positive hybrid vigour is desirable. While negative hybrid vigour is required for mortality percentage (MP), fifth instar duration (Fd), total larval duration (LD), number of cocoons per liter (C/L) for evaluation index were illustrated in Fig 15.

Where, hybrid HY A has the best results for the fifth duration, No of cocoon/liter, cocooning percentage, pupation ratio, crop/number, crop/weight, fecundity and fertility. And hybrid HY B showed better results for a number of cocoon/liter, cocooning percentage, pupation ratio, crop/number, crop/weight, fecundity and fertility. Imported hybrid G_1 demonstrated good results for the fifth duration, mortality percentage, cocooning percentage, pupation ratio, crop/number, crop/weight and fertility. And hybrid G_2 revealed best values for the fifth duration, larvae duration, mortality percentage, number of cocoon/liter, crop/weight and fertility.

Figure 16 containing data of the evaluation index mean for hybrids under study. Best data registered for HY A, HY B, G_2 and G_1, respectively. So, two hybrids are superior comparing to the imported hybrids.

These results are advocated with the findings of Seshagiri *et al.* (2013) who evaluated Twenty-four hybrid combinations used evaluation index value. They stated that, hybrid MSO_3 x APS_{45} with the highest evaluation index over multiple traits excelled over other combinations. Further, the combination recorded higher percent improvement over its control for all the 8 traits studied with the highest improvement was recorded for the trait shell weight.

Also, Ghazy and Mahmoud (2013) estimate the evaluation index value of thirteen single hybrids, hybrids for Giza of C, H, L, P and V have better values of the average of evaluation index.

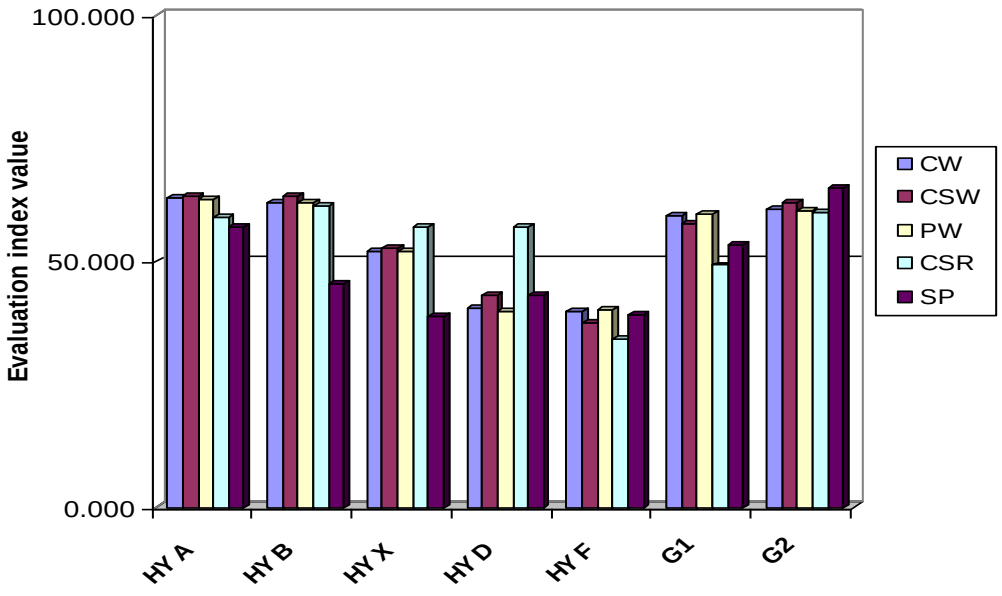

Fig.13. Evaluation index value for female of five local and two imported hybrids for five characters.

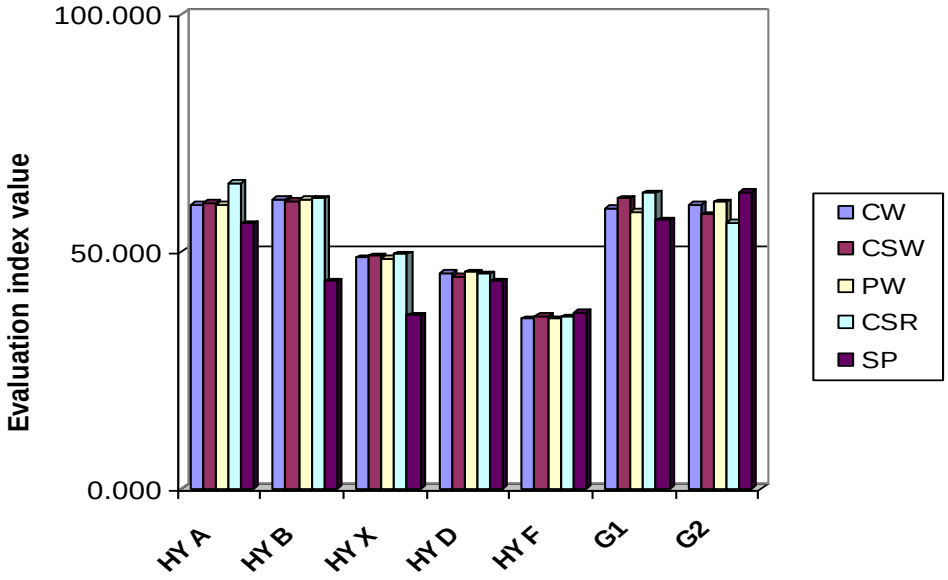

Fig.14. Evaluation index value for male of five local and two imprted hybrids.

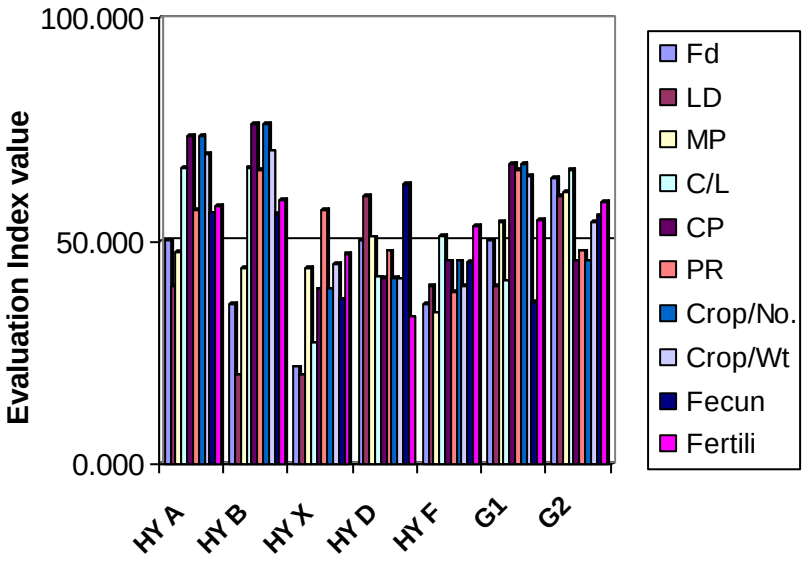

Fig.15.Evaluation index value of five local and two imprted hybrids for ten traits.

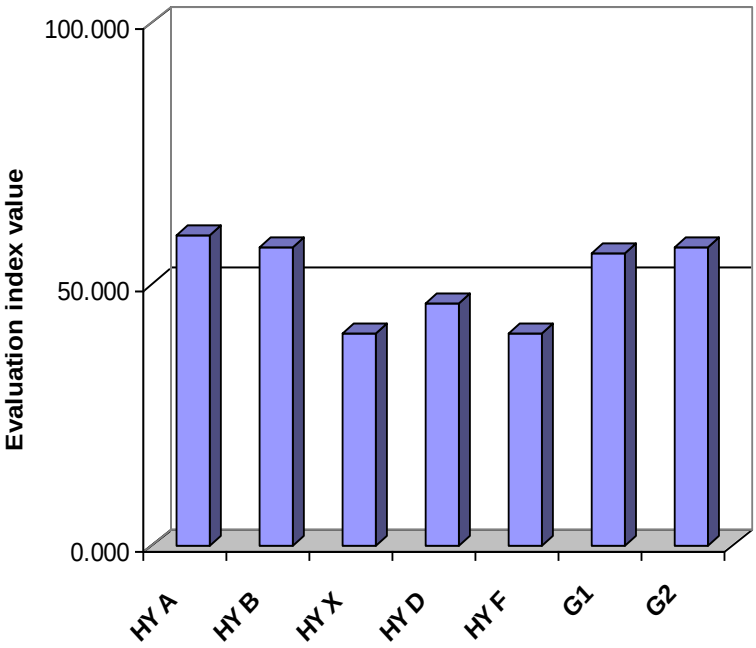

Fig.16. Average of Evaluation index value for five local and two imprted hybrids.

5-Subordinate Function:

Subordinate function values were recorded in Figures 17-20.

Data of CW, CSW, PW, CSR and SP for subordinate function were constituted in Figures. 17&18 for females and males. Hybrids of HY A, HY B, G_2 and G_1 got the best data for both females and males.

Higher data were documented of HY A for Fd, LD, MP, CP, Crop/No, Crop/W, Fecund and fertili characters. And hybrid G_1 for Fd, LD, MP, CP, PR, Crop/No, Crop/W and fertili traits. Also for hybrid G_2 of Fd, LD, MP, C/L, Crop/W and fertili characters (Fig. 19).

The cumulative subordinate function was settled in Fig. 20 for all hybrids under examination. Data raveled that G_2, HY A, G_1 and HY B hybrids acquired the highest results, respectively.

These results are accordance with those found by Ghazy (2014) who studied the subordinate function of thirteen single hybrids for nineteen characters. The highest value of the subordinate function was recorded for ten hybrids.

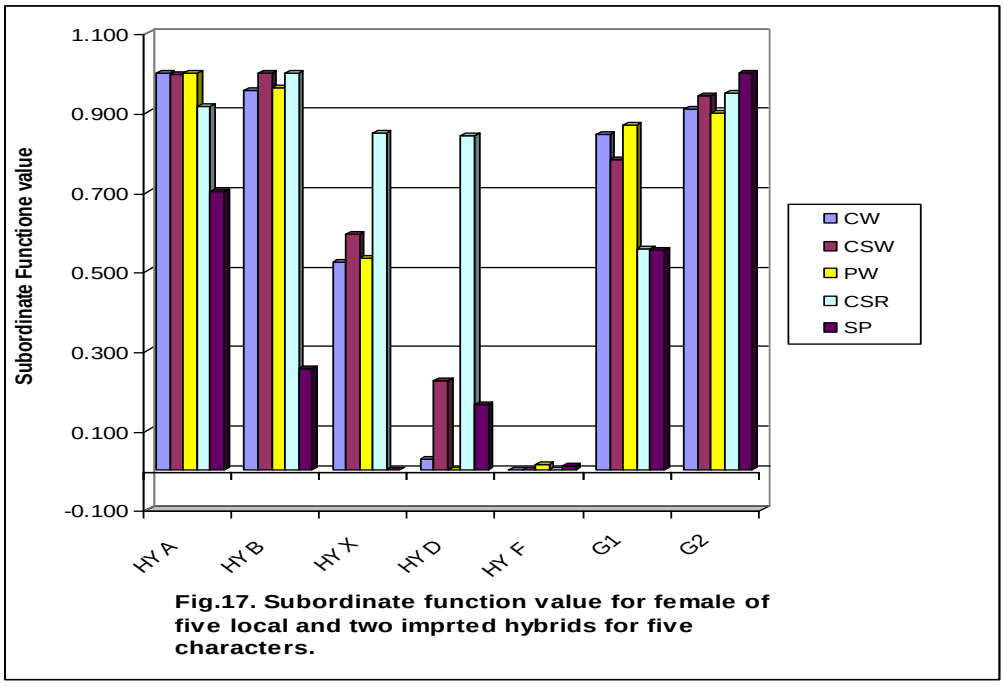

Fig.17. Subordinate function value for female of five local and two imprted hybrids for five characters.

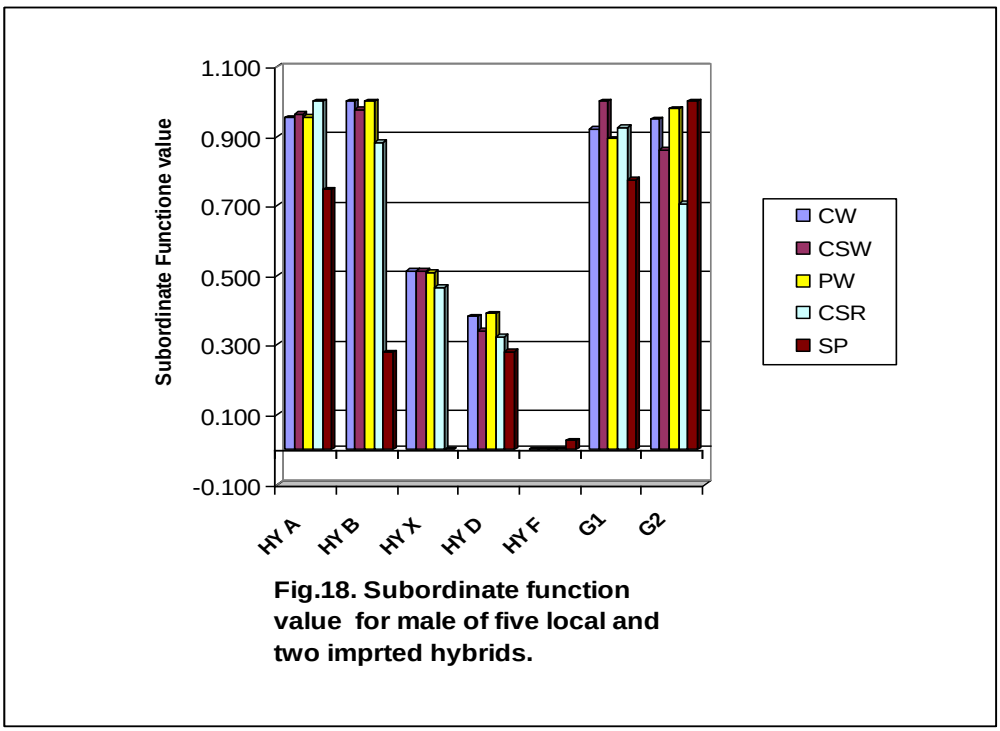

Fig.18. Subordinate function value for male of five local and two imprted hybrids.

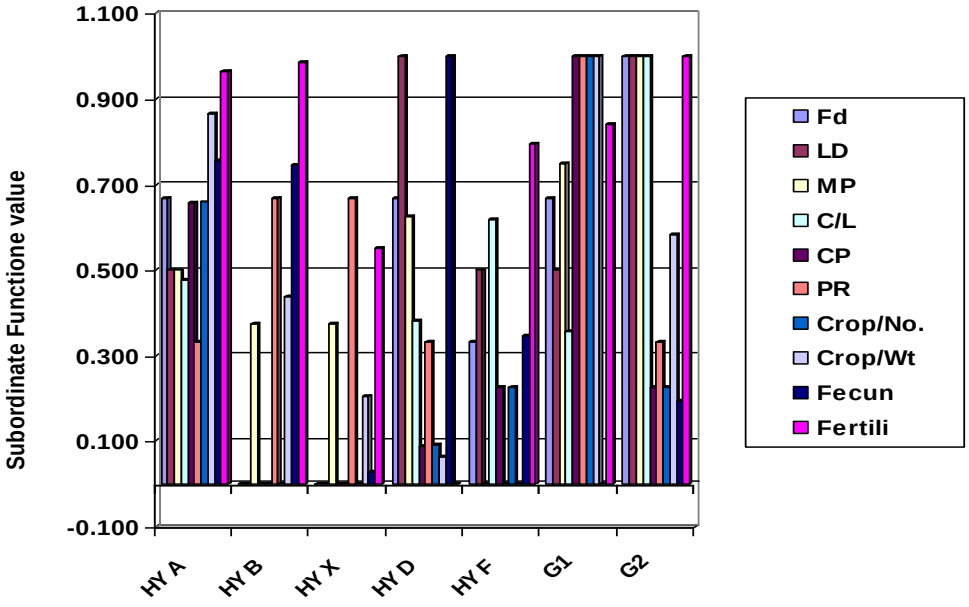

Fig.19.Subordinate function value of five local and two imprted hybrids for ten traits.

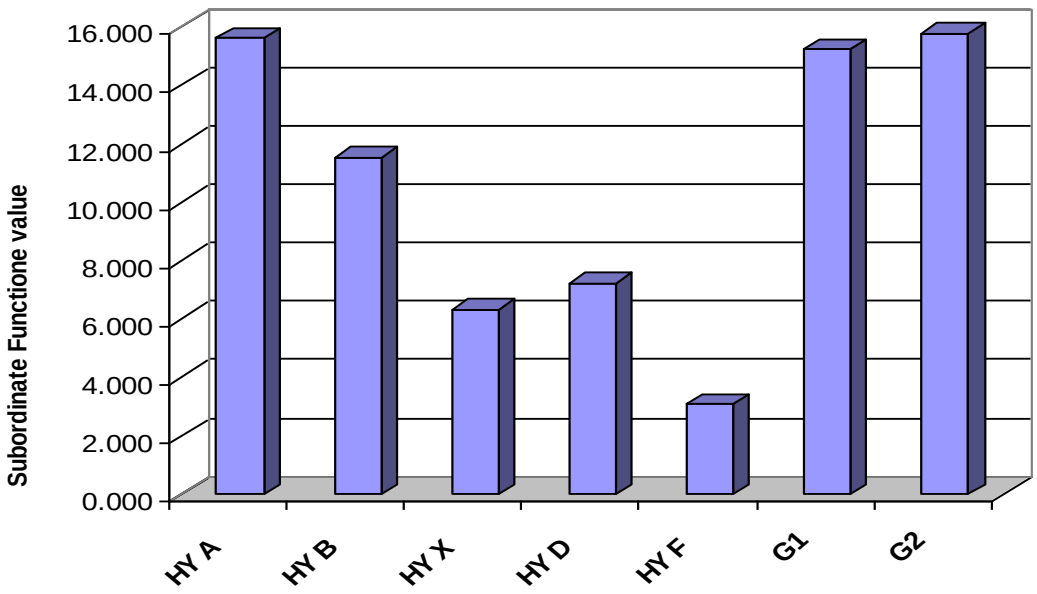

Fig.20. Cumulative of Subordinate function value for five local and two imprted hybrids.

6-Ranking of Local and Imported Hybrids:

Table 3. showed the ranking of the local and imported hybrids.

Data of average of evaluation index and cumulative of subordinate function were descending order. HY A and HY B hybrids ranking first and second order in the mean of evaluation index while it ranking second and four of cumulative and subordinate function. G_1 and G_2

ranking third and four for the average of evaluation index and first and third for cumulative and subordinate function.

Table.3. Ranking of some local and imported hybrids

Hybrids	Mean	Serial number	Cumulative	Serial number
HY A	59.422	1	15.615	2
HY B	57.178	2	11.528	4
G_2	56.991	3	15.759	1
G_1	55.889	4	15.236	3
HY D	46.412	5	7.227	5
HY F	40.709	6	3.095	7
HY X	40.657	7	6.324	6

CONCLUSION

Five local and two imported hybrids used in evaluated the heterosis over better, mid and check parent values. As well as the evaluation index value and subordinate function exploited to determine the best hybrids. The results revealed that, there aren't any hybrid earned best hybrid vigour over mid parent and better parent values for all traits together. HY A hybrid has the best heterosis for most characters understudy for mid and better parent values.

Generally, HY A exhibited hybrid vigour over check parent value (G_1) of most characters understudies, this hybrid is promising and can be used for commercial production. Also, hybrids of HY A and HY B represent hybrid vigour over check parent (G_2) for most characters. There are promising hybrids that can be exploited commercially. Best data registered for HY A, HY B, G_2 and G_1, respectively. So, two local hybrids are superior to the imported hybrids. G_2, HY A, G_1 and HY B hybrids acquired the highest results, respectively for cumulative subordinate function.

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ARABIC SUMMARY

تقدير قوة الهجين في بعض الهجن المحلية والمستوردة من ديدان الحرير *Bombyx mori* L.

تحية فؤاد

قسم بحوث الحرير-معهد بحوث وقاية النباتات- مركز البحوث الزراعية- جيزة- مصر.

تم إستخدام خمس هجن محلية وإثنان من الهجن المستوردة في هذه الدراسة، تم تقييم قوة الهجين في تلك الهجن علي حسب الإختلاف عن قيم متوسط الأباء وأفضل الأباء والأب الإختباري وبالمثل تم تقدير قيمة دليل التقييم Evaluation index و Subordinate function لصفات وزن الشرنقة، وزن غلاف الشرنقة ، وزن العذراء، نسبة المحتوي الحريري ، إنتاجية الحرير، لكلا من الإناث والذكور. وكذلك طول العمر الخامس، العمر اليرقي الكلي، نسبة الموت، عدد الشرانق في اللتر، نسبة التشرنق، نسبة التعذير، محصول الشرانق بالعدد والوزن، عدد االبيض الكلي /انثي ونسبة الخصوبة.

ولا يوجد هجين يمتلك قوة الهجين في كل الصفات معا، وبالنسبة لتقييم متوسط الاباء وأفضل الاباء أظهر الهجين HY A قوة هجين في معظم الصفات تحت الدراسة من حيث تقييم متوسط الاباء وأفضل الاباء وعامة الهجين HY A اظهر قوة هجين من حيث تقييم على اساس الاب الاختباري الاول G1 و G2 لمعظم الصفات تحت الدراسة. الهجين HY A حقق افضل النتائج لمعظم الصفات تحت الدراسة ومن المتوسط العام لدليل التقييم Evaluation index للهجن تحت الدراسة وكانت افضل الهجن هي HY A ، HY B ، G_2 و G_1 وكذلك الهجين HY A سجل أعلي قيم في Subordinate function لمعظم الصفات وبالنسبة للقيم التراكمية لـ Subordinate function اظهرت ان G_2 ، HY A، HY B و G_1 كانت افضل الهجن.