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Analysis of phenotypic stability for yield and yield components in bivoltine silkworm hybrids

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Abstract
Stability analysis was carried out to study stability in performance and genotype X environment interactions for 42 bivoltine silkworm hybrids reared in three seasons for three years. Stability statistics based on Eberhart and Russell approach were estimated for all the hybrids and traits. The G X E (linear) interaction was highly significant for all characters except shell%, when tested against pooled deviation, which revealed that there are wide genetic differences among hybrids for their regression on the environmental index. Considering high mean value and regression coefficient for most of the yield and yield components SK3 x BHR2 and O3 x D6 (P) found to be stable hybrids. Remaining hybrids seemed to be considerably influenced by Genotype X environment interactions and may be recommended for particular seasons.

Keywords: Bivoltine silkworm, Stability analysis, Seasons.

1. Introduction
The aim of any breeding programme is to improve crop production either within a given macro-environment or in a wide range of growing conditions [1, 2]. A successful cultivar needs to possess high and stable yield potential over a wide range of environmental conditions [3]. G x E interaction occurs widely in any breeding programme. It causes cultivars to perform different ranks in different environments and may cause selections from one environment to perform poorly in another. It is often used to refer to fluctuations of yield across the environments and force the breeders to check genotypic adaptation [4]. Knowledge of G x E interaction can help to reduce the cost of extensive genotype evaluation by eliminating unnecessary testing trials and by fine-tuning breeding programme [5]. G x E interaction is considered quantitative if the ranking of genotypes do not change in different environments [6]. A number of statistical methods are used for estimation of phenotypic stability. The classical parametric stability statistics are ecovalence, environment variance, regression coefficient, and sum of squared deviations from regression [7]. The silkworm *Bombyx mori* L. is an economically important and development of bivoltine silkworm hybrids, which can adapt wide range of diversified environments, is ultimate goal of any silkworm breeders involved in breeding programme. Some genotypes / hybrids may fair well in some environments but no so well in others. Therefore, an ideal approach is evaluation of hybrids for stability of performance under varying environmental conditions for yield and other traits. Therefore, the present investigation was carried out to identify stable hybrid by evaluating under diverse environments

2. Materials and Methods
2.1. Hybrid preparation and rearing
Six selected oval silkworm breeds *viz.*, MC3, O2, O3, O4, SK3, KPG-A and seven dumbbell silkworm breeds viz., SK4, SK6, BHR2, D4, D7, MJ1, D6(P) were crossed in lines x testers mating design and prepared 42 hybrids. These F1 hybrids were reared following completely randomized design (CRD) with three replications each and 300 larvae in each replication in three commercial crop seasons (autumn, spring and summer) for three years. The economically important parameters like fecundity, cocoon yield/ 10,000 larvae by number and weight, single cocoon weight (SCW), single shell weight (SSW), cocoon shell %, filament length (FL), denier, reelability%, raw silk% and neatness were collected.

2.2. Stability analysis

The stability analysis was done following Eberhart and Russel (1966) [5] model which interprets the variance of regression deviations as a measure of cultivar stability and the liner regression coefficient (β) as a measure of environmental index. In this model, mean (μ) and environmental index (Ij) are used as dependent and independent variables respectively to compute the regression coefficient. According to this model, an ideal genotype should have high mean (μ > X), a unit regression coefficient (βi=1) and no deviation from linearity (S2 di = 0).

The basic model for the Eberhart and Russel (1966) [5] model is:

$$Yij = \mu\, i + \square i\, Ij + \delta ij,$$

Where,
Yij= genotypic mean of ith genotype at jth environment.
μi= mean of ith genotype over all environments
βi= regression coefficient which measures the response of ith genotype to environments
Ij= environmental index as mean of all genotypes at jth environment minus the overall mean, and
δij= deviation from regression coefficient of ith genotype at jth environment

3. Results and Discussion

Pooled analysis of variance showed highly significant differences among the hybrids for all the traits studied (Table 1). The genotype x environment (G X E) interaction was further partitioned into linear and non-linear (pooled deviation) components. The G X E (linear) interaction was highly significant for six characters except shell%, when tested against pooled deviation, which revealed that there are wide genetic differences among hybrids for their regression on the environmental index. Estimates of environmental index (Table 2) for all the traits showed that spring was most favourable season for realizing yield potential of hybrids while summer was poor yielding environment. This shows that performance of the hybrids varied from season to season.

The stability parameters along with mean are presented in Table 3, 3a, 3b, 3c and 3d. Out of 42 hybrids, 20 hybrids manifested high mean performance for fecundity compared to grand mean but only three hybrids showed regression co-efficient around unity (bi=1). Hybrids like SK3 x BHR2, SK3 x D6(P) and O4 x D7 with higher mean than grand mean, regression co-efficient approaching 1 and non-significant S^2di confirmed their wide adaptation across the environments. In case of larval weight, hybrids viz., O2 x BHR2,O3 x BHR2, O4 x SK4, O4 x D6(P) and O4 x D7 possessed higher mean, bi<1 and lesser deviation of regression which indicated their stability in across the environments (Table 3).

In case of cocoon yield (number), SK3 x BHR2, O3 x D6(P), O4 x D4, MC3 x D6(P)and O4 x MJ1 showed higher mean with regression co-efficient approaching 1 and lesser deviation suggesting their adaptability over environments. However, SK3 x SK4, SK3 x SK6, O3 x BHR2 and O3 x D4 are with high mean but bi value lower than 1 indicating their suitability in favourable environments. O2 x D7 and MC3 x D6 (P) even though showed higher mean value but with higher bi value indicating their suitability in unfavourable environments. For cocoon yield/10000 larvae (wt), out of 42 hybrids, 25 hybrids showed higher cocoon yield. Of which only five hybrids (SK3 x BHR2, O2 x BHR2, O3 x D4, O4 x MJ1 and MC3 x D7) showed higher yield with regression co-efficient value around unity and low deviation of regression indicating relatively stable performance over environments(Table 3a). Hybrids like SK3 x D6(P), O2 x SK4, O2 x SK6, and O3 x D7 showed high mean value with bi value lesser than 1 indicating better performance in poor environment. Hybrids namely SK3 x SK4, SK3 x SK6, SK3 x D7, O3 x BHR2 and O4 x SK4 had high mean yield than grand mean with bi value more than 1 and low deviation of regression demonstrating its adaptability to favourable environment.

Only O4 x D4 showed stable performance for single cocoon weight with high mean and bi value nearing 1 and low deviation of regression. However, eleven hybrids showed higher mean with bi value more than 1 and lower deviation of regression predicting their better performance in favourable environment. Two hybrids [SK3 x D4 & O4 x MJ1] showed stable performance for shell weight with higher mean performance, bi value near to 1 and relatively low deviation of regression (Table 3b). In case of shell%, only one [O4 x D6 (P)] hybrid showed stable performance having high mean and bi value near 1 and relatively low deviation of regression. However, around nine hybrids showed higher mean compared to grand mean but with bi value more than 1 and low deviation suggesting their adaptability in favourable environment. Similarly three hybrids showed high mean but their bi value was lower than 1 which predicted their better potential in unfavourable environment (Table 3c).

As far as the filament length is concerned, though 20 hybrids have showed higher mean but not a single one showed by value around unity. But hybrids like SK3 x BHR2, SK3 x D7, O3 x BHR2 and O3 x D6(P) showed higher mean than grand mean with higher bi value indicating their suitability in favourable environments (Table 3c). In case of rawsilk, higher mean with bi value around 1 and lesser deviation was observed only in SK3 x D6 (P) suggesting the hybrid is stable over environment. However SK3 x SK4, O2 x SK4, O2 x SK6 and O3 x D6(P) found suitable for favourable environment due to their higher mean with bi value more than 1 and lesser deviation (Table 3d).

Table 1: Joint regression analysis of variance (SS: Sum of square; MSS: Mean sum of square) for different traits over environments in hybrids of bivoltine silkworm

		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS
Source	**Df**	**Fecundity**		**Larval weight**		**Yield/ 10000 Larvae (no.)**		**Yield/ 10000 Larvae (Wt.)**		**SCW**		**SSW**		**Shell%**		**FL**		**Raw Silk (%)**	
Hybrids (H)	41	234120	5710	695.9	16.97	12553637	306186	294.7	7.18	1.98	0.048	0.08	0.002	35.7	0.87	160547	3915	80	1.970
Environment (E)	2	27484.9	13742	375.8	187.93	2825 312	1412765	383.6	191.8	0.76	0.381	0.07	0.037	26.7	13.37	23012	11506	251	125.57
H x E	82	194843	2376	316.4	3.859	5867 8817	715595	382.2	4.66	1.53	0.019	0.05	0.001	41.8	0.51	202407	2468	273	3.338
E (H x E)	84	74109	-	230.7	-	2897 8043	-	255.2	-	0.76	-	0.04	-	22.8	-	75139	-	174	
E (Linear)	1	9161	-	125.2	-	9418 437	-	127.8	-	0.25	-	0.02	-	8.91	-	7670	-	83	
H x E (Linear)	41	25425	620.1	82.36	2.009	12884769	314262	40.5	0.98	0.19	0.005	0.009	0.00024	6.66	0.16	39833	971	87	2.133
Pooled deviation	42	39521	940.9	23.12	0.551	6674837	158924.7	86.8	2.06	0.31	0.008	0.009	0.00022	7.30	0.17	27636	658	3	0.090
Pooled error	252	6890.9	27.3	31.80	0.126	565910	2245.7	11.0	0.04	0.10	0.000	0.007	0.00003	2.35	0.009	5015	19	1	0.005

Table 2: Estimates of environmental Index

Season	Fecundity	Larval weight	Yield/ 10000 Larvae (no.)	Yield/ 10000 Larvae (Wt.)	SCW	SSW	Shell %	FL	Raw Silk (%)
Autumn	-9.62	-0.76	26.69	-0.40	-0.043	-0.014	-0.272	-10.97	0.53
Spring	11.11	1.41	320.71	1.38	0.062	0.019	0.361	4.43	0.62
Summer	-1.49	-0.65	-347.40	-0.99	-0.019	-0.005	-0.089	6.54	-1.15

Table 3: Estimates of stability analysis for fecundity and larval weight in bivoltine silkworm hybrids

Hybrids	Fecundity			Larval weight		
	Mean	bi	S^2di	Mean	bi	S^2di
SK3 x SK4	609	3.619	-925	41.48	2.082	-4.288
SK3 x SK6	601	-0.215	-208	43.29	2.751	-3.569
SK3 x BHR2	591	1.089	4050	42.80	0.301	-4.365
SK3 x D4	585	-2.117	-925	42.95	3.059	-4.03
SK3 x D6(P)	551	1.079	-778	46.48	0.021	-4.086
SK3 x D7	574	4.439	2220	43.88	1.689	-1.866
SK3 x MJ1	552	1.403	-868	44.60	0.072	-4.303
O2 x SK4	545	0.298	-646	47.09	0.327	-4.443
O2 x SK6	527	0.298	-646	47.76	0.304	-4.569
O2 x BHR2	595	1.753	164	44.75	1.067	-3.885
O2 x D4	559	0.783	-434	47.00	0.312	-3.408
O2 x D6(P)	618	-0.582	152	44.31	-0.509	-4.457
O2 x D7	624	-0.980	427	44.42	2.47	-4.164
O2 x MJ1	583	1.753	164	43.01	2.139	-3.730
O3 x SK4	547	3.113	2634	39.39	1.051	-3.226
O3 x SK6	509	1.642	313	47.33	1.418	-3.928
O3 x BHR2	576	3.712	2612	44.52	1.136	-4.526
O3 x D4	544	1.642	313	43.76	0.584	-4.301
O3 x D6(P)	657	2.414	-828	47.79	0.340	-4.522
O3 x D7	526	1.642	313	42.26	0.584	-4.301
O3 x MJ1	521	1.642	313	44.83	1.418	-3.928
O4 x SK4	652	-1.914	-537	44.46	1.066	-4.273
O4 x SK6	573	1.017	-808	47.58	1.061	-4.219
O4 x BHR2	575	0.812	-853	42.40	1.636	-4.087
O4 x D4	587	0.812	-853	44.70	1.636	-4.087
O4 x D6(P)	567	0.062	-928	48.43	1.061	-4.219
O4 x D7	561	1.017	-808	45.73	1.061	-4.219
O4 x MJ1	638	3.104	2209	45.92	1.842	-4.370
MC3 x SK4	489	1.696	-414	45.40	0.554	-4.396
MC3 x SK6	548	4.136	3414	39.75	1.548	-4.598
MC3 x BHR2	569	2.894	-590	42.28	1.614	-3.284
MC3 x D4	497	1.696	-414	43.90	0.554	-4.396
MC3 x D6(P)	493	2.315	-245	42.95	0.554	-4.396
MC3 x D7	510	-0.706	-929	42.97	1.343	-2.184
MC3 x MJ1	518	2.129	903	39.46	1.960	-4.203
KPGA x SK4	506	-0.303	-920	48.99	0.485	-3.367
KPGA x SK6	523	-0.303	-920	46.27	0.323	-4.582
KPGA x BHR2	536	-0.635	-920	44.80	2.373	-4.526
KPGA x D4	527	-0.303	-920	47.79	0.485	-3.367
KPGA x D6(P)	609	-3.017	-533	41.62	0.394	-4.590
KPGA x D7	515	-0.635	-920	45.52	0.323	-4.582
KPGA x MJ1	515	-0.303	-920	44.64	0.536	-4.256
Grand mean	560			44.51		

Table 3a: Estimates of stability analysis for yield / 10000 larvae (number) and yield / 10000 larvae (Wt.) in bivoltine silkworm hybrids

Hybrids	Yield / 10000 Larvae (number.)			Yield / 10000 Larvae (Wt.)		
	Mean	bi	S^2di	Mean	bi	S^2di
SK3 x SK4	9269	0.224	116853.940	16.34	1.293	0.515
SK3 x SK6	9062	0.240	742.371	17.03	1.620	-0.062
SK3 x BHR2	9257	0.825	-21945.793	17.74	1.173	1.244
SK3 x D4	9581	-0.076	-91813.1	17.51	1.351	-0.157
SK3 x D6(P)	9127	0.150	-87531.7	16.46	0.417	-0.400
SK3 x D7	9227	0.646	-3488.603	17.61	1.495	-0.765
SK3 x MJ1	9159	0.012	-91854.4	15.88	0.277	-0.683
O2 x SK4	9240	0.605	-858.281	16.68	0.493	-0.774
O2 x SK6	8717	0.410	-79741.047	16.38	0.259	-0.694
O2 x BHR2	9330	0.473	-11126.576	18.52	0.967	2.350
O2 x D4	9282	0.473	-11126.576	17.55	0.440	-0.758
O2 x D6(P)	8974	-0.273	1585320.31	17.88	1.276	17.977
O2 x D7	9019	1.356	-91656.5	18.35	1.392	0.348

O2 x MJ1	9405	0.473	-11126.576	17.73	0.746	0.068
O3 x SK4	8767	1.394	-71384.236	14.51	1.206	-0.751
O3 x SK6	8686	0.724	-74498.559	15.99	0.357	-0.633
O3 x BHR2	9002	0.378	4666.773	18.17	1.772	0.129
O3 x D4	9008	0.493	49061.592	17.83	1.062	2.605
O3 x D6(P)	9146	0.956	-12750.921	19.30	1.598	1.476
O3 x D7	8961	0.485	96155.68	16.06	0.238	0.572
O3 x MJ1	8698	0.724	-74498.55	15.07	0.539	-0.844
O4 x SK4	8605	1.767	-42868.023	16.90	1.834	-0.164
O4 x SK6	8567	0.105	-94307.1	14.73	0.448	-0.030
O4 x BHR2	8573	0.105	-94307.1	14.36	0.507	-0.076
O4 x D4	8991	1.075	-58997.387	17.46	1.333	-0.398
O4 x D6(P)	8379	-0.009	-94134.2	14.84	0.236	-0.427
O4 x D7	8599	0.105	-94307.1	14.40	0.448	-0.024
O4 x MJ1	9174	0.996	31574.097	18.18	1.176	0.462
MC3 x SK4	8746	1.254	300306.431	13.64	0.111	0.424
MC3 x SK6	9383	0.450	-79720.375	16.49	0.884	-0.717
MC3 x BHR2	9119	0.379	145588.477	16.24	0.820	-0.767
MC3 x D4	8802	1.254	300306.431	13.07	0.095	0.293
MC3 x D6(P)	9058	1.248	298556.486	14.60	0.457	2.909
MC3 x D7	8999	-0.83	-6376.369	15.81	0.969	1.412
MC3 x MJ1	9401	-0.025	-64009.450	16.08	0.764	-0.359
KPGA x SK4	8547	3.18	119097.517	14.13	1.525	3.147
KPGA x SK6	8530	3.19	119097.517	14.91	1.615	3.678
KPGA x BHR2	8576	3.19	119097.517	14.72	1.902	2.782
KPGA x D4	8509	3.19	119097.517	14.64	1.585	3.495
KPGA x D6(P)	8459	4.30	425665.953	14.80	1.865	8.426
KPGA x D7	8558	3.18	119097.517	14.75	1.907	2.809
KPGA x MJ1	8565	3.18	119097.517	14.35	1.549	3.286
Grand mean	8957			15.74		

Table 3b: Estimates of stability analysis for single cocoon weight and single shell weight in bivoltine silkworm hybrids

Hybrids	Single Cocoon Weight			Single Shell Weight		
	Mean	bi	S^2di	Mean	bi	S^2di
SK3 x SK4	1.801	1.7612	-0.002	0.361	1.692	-0.00032
SK3 x SK6	1.837	1.8614	0.001	0.371	1.661	-0.0001
SK3 x BHR2	1.907	1.9142	0.008	0.356	1.815	-0.00038
SK3 x D4	1.789	1.8352	-0.0060	0.354	1.152	-0.00036
SK3 x D6(P)	1.813	0.4385	-0.002	0.362	0.310	-0.0001
SK3 x D7	1.928	2.8346	-0.0048	0.378	2.985	-0.00038
SK3 x MJ1	1.733	0.4354	-0.002	0.345	0.838	-0.0002
O2 x SK4	1.805	0.1803	-0.0060	0.349	0.734	-0.00034
O2 x SK6	1.880	0.1803	-0.0060	0.365	0.528	-0.00041
O2 x BHR2	1.983	2.1836	0.0009	0.373	1.449	-0.0001
O2 x D4	1.890	0.1803	-0.0060	0.374	0.734	-0.00034
O2 x D6(P)	1.942	2.1458	0.006	0.385	1.712	-0.00033
O2 x D7	1.996	1.3194	0.010	0.393	1.533	0.0005
O2 x MJ1	1.903	2.1836	0.0009	0.359	1.640	-0.0002
O3 x SK4	1.641	0.5399	0.005	0.311	0.434	0.0002
O3 x SK6	1.840	0.1962	-0.004	0.366	1.432	-0.00038
O3 x BHR2	1.933	3.325	-0.001	0.366	2.086	-0.00038
O3 x D4	1.925	1.5964	-0.0047	0.366	1.432	-0.00038
O3 x D6(P)	2.035	2.4358	0.012	0.405	2.098	0.0003
O3 x D7	1.790	0.1237	-0.001	0.359	1.432	-0.00038
O3 x MJ1	1.732	0.4168	-0.0061	0.332	0.880	-0.00039
O4 x SK4	2.000	1.4309	0.021	0.385	1.426	0.0004
O4 x SK6	1.721	0.3586	0.010	0.329	0.442	-0.0001
O4 x BHR2	1.676	0.5127	0.011	0.315	0.442	-0.0001
O4 x D4	1.875	1.1305	-0.0053	0.345	0.878	-0.00041
O4 x D6(P)	1.773	0.2017	0.001	0.367	0.425	-0.0001
O4 x D7	1.676	0.3586	0.010	0.323	0.442	-0.0001
O4 x MJ1	1.964	1.3624	-0.0053	0.380	0.838	-0.00038
MC3 x SK4	1.559	0.3603	-0.0054	0.295	0.107	-0.00039

MC3 x SK6	1.766	0.9762	-0.001	0.328	0.761	-0.0001
MC3 x BHR2	1.780	0.7476	-0.0058	0.340	0.560	-0.00037
MC3 x D4	1.485	0.3603	-0.0054	0.293	0.291	-0.00038
MC3 x D6(P)	1.608	0.0900	0.0004	0.299	-0.122	-0.0002
MC3 x D7	1.782	1.0720	0.005	0.332	0.542	-0.0002
MC3 x MJ1	1.728	1.4411	-0.0062	0.337	1.505	-0.00041
KPGA x SK4	1.639	0.5649	0.005	0.313	0.447	-0.0002
KPGA x SK6	1.736	0.5649	0.005	0.343	0.709	0.0001
KPGA x BHR2	1.701	1.4014	0.008	0.338	1.079	0.00003
KPGA x D4	1.707	0.5649	0.005	0.319	0.447	-0.0002
KPGA x D6(P)	1.743	0.0681	0.003	0.350	0.764	-0.00032
KPGA x D7	1.708	1.4014	0.008	0.335	0.734	0.0003
KPGA x MJ1	1.662	0.5649	0.005	0.336	0.709	0.0001
Grand mean	1.795			0.348		

Table 3c: Estimates of stability analysis for shell% and filament length in bivoltine silkworm hybrids

Hybrids	Shell%			Filament Length		
	Mean	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**
SK3 x SK4	20.03	1.567	-0.238	905	1.938	-1151.83
SK3 x SK6	20.14	1.255	-0.246	896	5.246	-196.918
SK3 x BHR2	18.62	1.545	0.425	922	4.499	-1031.818
SK3 x D4	19.84	-0.187	0.097	902	7.536	-1095.10
SK3 x D6(P)	19.98	0.202	-0.191	977	-0.196	-625.495
SK3 x D7	19.38	3.272	0.398	956	4.367	-625.821
SK3 x MJ1	19.89	1.770	-0.247	932	0.317	-969.207
O2 x SK4	19.32	1.944	0.103	949	-0.618	-1062.406
O2 x SK6	19.41	1.257	-0.208	968	-0.585	-1080.30
O2 x BHR2	18.82	0.229	-0.208	945	-1.540	-445.077
O2 x D4	19.77	1.845	0.077	966	-0.316	-1152.02
O2 x D6(P)	19.76	0.719	0.176	941	-2.202	772.507
O2 x D7	19.58	1.939	-0.049	906	5.888	827.674
O2 x MJ1	18.80	0.767	-0.222	954	1.412	-258.566
O3 x SK4	18.92	0.166	-0.097	881	2.082	-367.345
O3 x SK6	19.91	3.805	-0.197	919	-0.532	-889.089
O3 x BHR2	18.90	0.082	-0.102	919	2.400	-1017.519
O3 x D4	19.28	0.993	0.025	931	-0.413	-994.312
O3 x D6(P)	19.86	1.320	-0.239	964	2.261	-268.858
O3 x D7	19.45	0.344	-0.191	907	-0.532	-889.089
O3 x MJ1	19.19	1.977	-0.158	902	-0.532	-889.089
O4 x SK4	19.20	1.300	-0.236	912	-0.110	3954.138
O4 x SK6	19.12	0.871	0.008	902	2.380	-1140.84
O4 x BHR2	18.80	0.650	0.034	836	0.448	567.453
O4 x D4	18.41	0.527	-0.195	883	1.503	701.614
O4 x D6(P)	20.69	1.033	-0.231	909	1.225	-1148.25
O4 x D7	19.30	0.890	0.037	881	2.705	-1152.05
O4 x MJ1	19.32	0.007	-0.248	873	-2.489	804.916
MC3 x SK4	18.92	1.031	0.181	899	0.209	-761.539
MC3 x SK6	18.54	0.629	-0.221	865	0.484	973.739
MC3 x BHR2	19.05	0.340	0.054	869	0.402	-981.181
MC3 x D4	19.78	1.744	0.398	879	0.209	-761.539
MC3 x D6(P)	18.60	-0.116	-0.242	867	0.209	-761.539
MC3 x D7	18.64	-0.454	0.021	858	5.287	-170.575
MC3 x MJ1	19.41	1.796	-0.248	836	3.338	-1096.32
KPGA x SK4	19.12	0.483	0.075	895	-2.058	-1122.46
KPGA x SK6	19.76	1.201	-0.213	940	-0.112	-770.332
KPGA x BHR2	19.85	0.721	-0.178	953	-0.112	-770.332
KPGA x D4	18.69	0.484	0.020	913	-2.058	-1122.46
KPGA x D6(P)	18.72	1.014	-0.185	948	0.498	-903.288
KPGA x D7	19.63	-0.198	-0.233	953	-0.112	-770.332
KPGA x MJ1	20.20	1.233	-0.220	910	-0.327	-908.930
Grand mean	19.35			902		

Table 3d: Estimates of stability analysis for raw silk% in bivoltine silkworm hybrids

Hybrids	Raw silk%		
	Mean	bi	S^2di
SK3 x SK4	13.23	1.480	-0.701
SK3 x SK6	12.97	1.678	-0.528
SK3 x BHR2	12.17	1.885	-0.705
SK3 x D4	12.95	2.245	-0.480
SK3 x D6(P)	14.47	0.906	-0.688
SK3 x D7	12.98	1.806	-0.702
SK3 x MJ1	13.36	0.942	-0.689
O2 x SK4	13.06	1.707	-0.533
O2 x SK6	13.81	1.708	-0.533
O2 x BHR2	12.89	1.707	-0.533
O2 x D4	12.98	1.707	-0.533
O2 x D6(P)	12.57	1.459	-0.636
O2 x D7	12.35	1.785	-0.645
O2 x MJ1	11.97	1.7075	-0.533
O3 x SK4	12.97	1.388	-0.1189
O3 x SK6	13.40	0.828	-0.690
O3 x BHR2	12.22	0.533	-0.643
O3 x D4	12.96	1.706	-0.697
O3 x D6(P)	13.71	1.483	-0.695
O3 x D7	12.89	1.700	-0.697
O3 x MJ1	12.55	0.828	-0.690
O4 x SK4	12.42	2.086	-0.707
O4 x SK6	13.89	0.169	-0.575
O4 x BHR2	11.72	0.392	-0.463
O4 x D4	12.36	0.937	-0.428
O4 x D6(P)	14.33	0.134	-0.706
O4 x D7	13.14	0.169	-0.575
O4 x MJ1	12.26	1.700	-0.637
MC3 x SK4	12.18	0.746	-0.612
MC3 x SK6	12.04	1.827	-0.704
MC3 x BHR2	11.91	1.826	-0.707
MC3 x D4	12.13	0.746	-0.612
MC3 x D6(P)	11.88	0.746	-0.612
MC3 x D7	12.45	1.902	-0.678
MC3 x MJ1	14.75	-3.898	-0.700
KPGA x SK4	14.16	0.071	-0.703
KPGA x SK6	13.94	0.246	-0.604
KPGA x BHR2	13.84	0.246	-0.604
KPGA x D4	14.25	0.071	-0.703
KPGA x D6(P)	13.75	0.188	-0.682
KPGA x D7	13.84	0.246	-0.604
KPGA x MJ1	13.86	0.246	-0.604
Grand mean	13.04		

The stability proposed by Eberthart and Russel (1966) [5] has been widely used in crop plants [8-11] and in silkworm, *Bombyx mori* [12-14]. The goal of a breeder is to select one or more good varieties. Before a decision can be made a careful analysis of phenotypic, genotypic and environmental variations & genotype x environmental interaction is necessary. The objective of this study is to predict the selection of a hybrid based on the observations existing in the populations. On the other hand it will help us to understand how an organism's phenotype is influenced by its genotype and the environment in which it was developed and exists. The ideal genotype as proposed by Eberthart and Russel (1966) [5] could have a high mean over range of environments, a regression coefficient of one and deviation mean square from regression of zero. Genotypes with regression coefficient is greater than one could be approved for more favourable environment, while those with coefficient less than one would be relatively better adapted to less favourable condition. The pooled analysis of variance for stability revealed significant genetic variability for the traits studied, as well as the environment indicating differential effect of each environment. Further, partitioning of G x E interaction into G x E (linear) and pooled deviations (non-linear) revealed significance of both indicating that both components accounted for G x E interaction. The highly significant differences ($P<0.01$) in the environment and hybrids indicate the fluctuation of genotypes in their responses to the different environments. The deviation from regression for majority of the hybrids was highly significant that revealed the response of these hybrids was unpredictable and that they were more suitable for sites with better environments. The regression of genotype mean yield on the environmental index resulted in regression coefficients showed larger variation. This indicates performance of hybrids varied with environments.

4. Conclusion

The simultaneous consideration of three parameters of stability for the individual hybrid revealed that the hybrids SK3 x BHR2 and O3 x D6(P) gave the higher mean for yield and yield contributing traits with the regression values around unity and lesser deviation from regression indicating the stability over the seasons. Hybrids viz., SK3 x SK6, SK3 x D6(P), SK3 x SK4 and O3 x D4 have showed higher mean with bi value more than 1 and high values of S^2di, indicates that these hybrids are expected to give good yield under favourable environmental conditions.

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