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Inbreeding Depression Analysis for Yield and Some of its Associated Characters in Late Sown Condition in Bread Wheat (*Triticum aestivum* L.em. Thell)

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A B S T R A C T

In order to study inbreeding depression for yield and some of its associated characters in bread wheat (*Triticum aestivum* L.em. Thell) over the environments, the present experiment was carried out performing diallel analysis following Griffing (1956) Method II Model I. Ten genetically diverse parents were selected and crossed in half diallel fashion excluding reciprocals. These parents were evaluated along with their 45 F_1's and 45 F_2's in a randomized block design with 3 replications over three environments namely, normal sown (E_1), late sown (E_2) and very late sown (E_3) environments created by using three different dates of sowing. In the present experiment significant inbreeding depression was reported for different traits in all the three environments. Even though, none of the cross displayed significant inbreeding depression in desired direction for all the characters and in all the environments but HD 2967 X DBW 88 was found as desirable cross combination in E_3 environment as it showed desirable (significant negative) inbreeding depression for grain yield per plant and some other traits.

Introduction

Wheat one of the most important food crop and cereal crop remains the third most produced food grain in world a cereal crop. There is noteworthy production in the production and productivity of wheat but still it needs much more improvement the yield and quality of wheat as it is a staple good of more than one billion people and still the population is burgeoning. The fundamental objective of most of plant breeding programmes remain to increase yield of concerned crop by developing improved varieties through heterotic expression which is expected to decline in F_2 generation due to decrease in heterozygosity and referred as inbreeding depression.

The estimates of heterosis and inbreeding depression together provide information about the type of gene action involved in the expression of various quantitative traits. The mating between more closely related individuals is known as inbreeding. The closest form of inbreeding is self-fertilization.

The genetic effects of inbreeding on cross-fertilizing crops are as follows (Falconer, 1981).

Homozygosity is increased which results in fixation of genes. The recessive deleterious genes come to the surface due to release of hidden genetic variability from heterozygotes. These recessives are exposed to natural selection.

The heterozygosity is reduced rapidly because inbreeding results in elimination of hybrids from a population and replaces them with pure types. Thus, inbreeding leads to purity of types.

The populations mean is reduced due to decrease in the number of hybrid genotypes, which have more number of dominant genes.

Genetic correlation increases between close relatives due to increase in the prepotency, which increases with homozygosity.

The variability, which is hidden in heterozygote, is made free through inbreeding. Thus, the total variability is increased without selection. With selection the variability is reduced towards the direction of selection.

The inbreeding depression refers to decrease in fitness and vigour due to inbreeding. The degree of inbreeding is measured by the inbreeding coefficient. Inbreeding depression results are due to fixation of unfavorable recessive genes in F_2, while in case of heterosis the unfavorable recessive genes of one line or parent are covered by favorable dominant genes of other parent. The fixation of all favorable dominant genes in one homozygous line is impossible due to linkage between some unfavorable recessive and favorable dominant genes. In the present study Inbreeding depression is studied and analysis under three environments viz. normal. Late and very late sown conditions which are indicated as E_1, E_2 and E_3 respectively.

Materials and Methods

On the basis of genetic diversity and their stability for different yield traits, ten diverse wheat varieties selected as the experimental material and crossed in diallel mating fashion excluding reciprocals to obtain 45 F_1s in *rabi* 2014-2015. In *Rabi* 2015-16 ten genotypes along with their 45 F_1's and 45 F_2's (obtained at IARI, regional station, Wellington, TN during *kharif* 2015) progenies were evaluated using Randomized Block in 3 replications over three environments created by three different dates of sowing *viz*. 15 Nov., 5 Dec. and 25 Dec. at Agricultural Research Farm of RARI, Durgapura.

Observations were recorded on days to heading (Days), days to maturity (Days), grain filling period (Days), plant height (cm.), flag leaf area (cm^2), number of tillers per plant, spike length (cm), number of grains per spike, 1000-seed weight (g), harvest index (%) and grain yield/plant (g). Mean values over selected plants were used for statistical analysis.The mean values of different F_1s and F_2s for all characters were subjected for analysis of inbreeding depression as per cent increase or decrease in the mean value of F_2 over F_1.

Results and Discussion

The heterotic expression normally decreases in F_2 generation as the dominance or dominance interaction effects dissipate in this generation due to reduced heterozygosity, resulting into inbreeding depression. In present experiment, significant inbreeding depression was reported for different traits in all the three environments.

Table.1.1 Estimates of inbreeding depression

	Days to Heading E1	Days to Heading E2	Days to Heading E3	Days to Maturity E1	Days to Maturity E2	Days to Maturity E3	Grain Filling Period E1	Grain Filling Period E2	Grain Filling Period E3
P1XP2	-2.331*	2.990*	1.987	-0.763	-1.246	-0.719	0.927	-6.161	-26.583**
P1XP3	-0.962	3.856*	0.852	-1.305	-0.901	-1.071	2.243	-6.738	23.428**
P1XP4	-1.095	2.724*	2.243	0.055	-1.223	-1.460	-1.442	-7.959**	-60.290***
P1XP5	1.350	3.505*	1.658	-0.524	-1.488	-1.060	2.969	-9.650**	-19.378**
P1XP6	3.084**	2.288**	1.429	-1.240	-1.282	-1.852	0.120	-7.388	-11.658*
P1XP7	1.396	2.451	1.105	-1.378	-1.250	-1.873	2.005	-5.621*	-38.045***
P1XP8	4.000	3.197*	-0.067	1.416	-1.266	-1.449	0.701	-7.609	-8.366
P1XP9	-0.457	2.851	2.281	0.545	1.458	-1.418	2.702	-7.822**	1.042
P1XP10	0.826	1.871*	2.138	0.254	-0.307	-0.719	-2.179	-9.484	-25.908***
P2XP3	2.548*	2.570	1.657	-0.992	-0.904	-0.364	-0.306	-5.583*	-50.032***
P2XP4	-1.608	3.962*	0.751	-0.775	1.994	-0.362	1.726	-6.167	-47.209***
P2XP5	-0.541	2.603***	2.139	-0.182	2.609	-2.290	-2.547	-5.379	-39.516***
P2XP6	0.172	2.767*	1.596	1.326	0.619	-1.838	0.899	-6.982*	-45.004**
P2XP7	2.416*	3.548	1.563	1.818	0.197	-1.128	3.220	-6.660	-0.307
P2XP8	-0.463	2.642	1.992*	-0.353	2.849	-1.103	3.500	-4.949	-33.201***
P2XP9	0.573	2.857	3.191*	-0.771	-1.112	-1.083	-0.879	-2.802	-12.006
P2XP10	0.000	3.996**	1.524	-0.088	6.497**	-1.465	3.842	-5.445	1.809
P3XP4	-0.728	2.510	0.541	-0.512	0.306	-1.792	3.408	-7.889	18.692**
P3XP5	0.701	3.225	2.131	0.508	3.768	-1.413	4.321	-5.860	3.596
P3XP6	1.900	2.347	2.094	0.850	2.128	-1.449	-0.736	-5.323*	-5.892
P3XP7	1.429	3.302	1.613	-1.238	0.000	-1.852	2.342	-10.406**	-2.679
P3XP8	-0.236	3.318*	2.122*	-1.028	-0.909	-2.281	0.178	-6.113*	1.364
P3XP9	0.420	3.391*	3.134**	-0.126	1.739	-2.273	4.648*	-7.692*	-2.714
P3XP10	0.126	2.780	2.162*	-4.810**	0.000	-2.239	-0.494	-7.005*	-11.901
P4XP5	1.809	2.724	0.992	-1.235	3.395**	-0.692	2.158	-5.670	15.862**
P4XP6	0.299	2.161	1.093	-0.838	-0.901	-1.034	3.593	-7.571**	-80.092***
P4XP7	-1.571	2.439	1.130	0.787	-1.307	1.767	1.338	-9.353	-67.012***
P4XP8	0.794	2.315	1.483	-0.942	0.912	-0.730	-4.430	-5.068	-15.338
P4XP9	0.823	3.070	2.247	-0.773	-0.901	-1.429	3.130	-3.487	-37.281***
P4XP10	1.317	2.729	0.939	-1.064	2.586	-0.348	3.017	-7.538	-62.695***
P5XP6	-0.261	2.666	0.532	0.549	3.254	-1.370*	4.552	-7.053	-71.734***
P5XP7	-0.704	3.330	1.124	0.552	-0.331	-1.730	-1.183	-7.662**	-8.501
P5XP8	0.885	2.315	1.656	-0.811	-0.926	-0.690	5.969*	-6.927**	-11.317**
P5XP9	0.919	4.245	1.648	-0.220	-1.603	-1.053	3.395	-9.255**	-46.530***
P5XP10	1.377	5.508***	1.053	1.429	6.079*	-0.678	2.050	-11.452**	-40.261***
P6XP7	1.396	7.583**	2.775	0.000	-1.235	-1.370	1.205	-0.471	-45.740***
P6XP8	-1.667	9.019**	1.070	-0.257	-1.526	-1.014	0.401	-7.020	2.557
P6XP9	-1.293	-7.263**	1.413	-1.282	-0.612	-1.003	9.818*	-5.065	-46.316**
P6XP10	-0.661	3.982	1.905	0.251	2.286	-0.304	-8.004*	-7.535*	-43.158**
P7XP8	-1.708	1.990	2.968	-1.676	-0.965	-0.699	17.813**	-11.110**	-3.326
P7XP9	-0.008	3.389	1.124	0.741	0.872	-1.481	9.411	-5.149	-13.444**
P7XP10	-1.716	5.136*	2.377	-1.667	-0.664	-1.429	0.784	-4.208	-23.001**
P8XP9	-0.400	2.279	1.657	0.249	0.301	-1.056	4.488	-6.765	-40.173**
P8XP10	-0.707	2.358	2.551	-0.826	-0.619	-1.515	3.119	-8.397	-26.707**
P9XP10	0.172	2.290	1.124	-1.312	2.882	-1.465	-2.458	-6.596*	-28.185***
Average	**0.251**	**3.032*** **	**1.666*** **	**-0.400**	**0.569**	**-1.186***	**2.078**	**-6.715*** **	**-19.955*** **

Table.2 Estimates of inbreeding depression

	Plant Height cm E1	Plant Height cm E2	Plant Height cm E3	Flag Leaf Area cm² E1	Flag Leaf Area cm² E2	Flag Leaf Area cm² E3	Tillers/ Plant E1	Tillers/ Plant E2	Tillers/ Plant E3
P1XP2	2.158	-1.176	2.101*	7.540	4.352	8.083	14.286	6.129	14.170
P1XP3	-1.534	-1.008	0.608	5.849	1.744	7.485	18.875	16.780	7.909
P1XP4	-0.676	-1.772	-1.366	13.834	-2.959	10.551	50.000	13.913	29.923
P1XP5	-1.093	-2.518	3.496*	11.292	5.509	8.667	3.138	5.950	7.742
P1XP6	-0.313	-0.658	3.646*	13.766**	0.000	9.706	12.500	14.702	-14.870
P1XP7	-1.240	-0.809	-1.587	11.300	3.258	-2.130	18.182	20.524	24.675
P1XP8	1.046	-2.308	1.112	24.968***	4.555	10.521	8.333	25.208	18.153
P1XP9	3.368*	-1.328	-1.159	20.352*	1.752	10.194	-28.571	15.067	-1.732
P1XP10	-1.417	-1.219	-2.114	14.356	3.865	1.390	-24.388	14.610*	30.720
P2XP3	6.490	-1.379	0.638	20.424	5.265	-9.583	-12.500	24.806	48.987*
P2XP4	5.002**	-15.641**	1.558	17.286	1.940	1.931	10.048	16.747	12.309
P2XP5	3.948	-3.115	0.959	13.945	16.357	10.563	24.471	21.585	24.620
P2XP6	-1.426	-2.253	-0.210	9.904**	3.470	8.073	8.056	27.654	0.645
P2XP7	-5.376***	-3.529**	-3.550	6.756	-6.125	-41.077	-12.500	22.321	22.374
P2XP8	8.172***	-1.849	1.200	17.881	4.522	5.306	7.619	13.255	24.348
P2XP9	3.266*	-1.011	-1.681	19.253**	5.525	-12.876	16.000	7.612	25.112
P2XP10	-11.358*	-1.001	-4.580	6.502	2.528	7.884	9.167	23.993	29.235
P3XP4	-1.587	-0.977	-1.139	6.218	5.699	14.776	26.435	11.614	7.720
P3XP5	-12.207***	-1.310	-0.725	8.217	4.678	-9.880	-16.667	14.556	-27.778
P3XP6	6.241***	-1.447	0.949	27.332***	3.705	-24.904	-37.619*	17.232	12.425
P3XP7	-1.698	-0.764	-1.673	13.697	3.449	8.824	-13.636	24.027	15.625
P3XP8	1.116	-1.279	1.139	21.365	3.696	8.112	4.167	10.636	29.140
P3XP9	-0.218	-0.816	1.244	26.019**	1.957	9.028	25.000	18.280	1.201
P3XP10	1.905	-1.419	1.392	5.449	18.032	2.636	-7.066	20.788	8.007
P4XP5	-0.080	-1.071	1.326	-1.791	2.506	15.219	11.111	21.504	-4.407
P4XP6	2.148	-1.093	-0.050	31.773***	12.504	9.107	8.333	9.097	28.314
P4XP7	0.133	-1.081	1.375	22.235*	6.099	10.572	-12.676	15.939	27.803
P4XP8	-1.250	-2.720	0.803	4.814	3.696	5.496	-2.857	19.786	9.082
P4XP9	2.926	-1.330	1.078	-5.815	5.525	5.523	9.524	17.097	-19.134
P4XP10	0.830	-1.911	1.926	-3.110	5.740	-10.664	0.111	19.908	13.713
P5XP6	1.919	-0.697	1.061	26.877***	3.292	-18.535	0.000	15.476	-10.819
P5XP7	-0.806	-0.606	1.983	33.148*	2.006	6.985	0.000	18.034	17.619
P5XP8	1.924	-1.492	0.789	35.971**	1.123	-3.477	9.091	20.755	32.807
P5XP9	10.432**	-0.832	-3.248	31.209***	11.376	2.282	0.000	15.647	26.667*
P5XP10	-10.161***	-2.226	-0.995	6.275	6.242	-2.674	13.995	28.054	0.486
P6XP7	-1.435	-2.074	-2.133	15.784	3.348	-18.569	-15.789	16.760	2.130
P6XP8	2.985**	-1.698	-0.412	7.000	2.482	-8.576	16.667	5.751	21.442
P6XP9	0.537	-0.447	-0.461	12.136	7.067	-12.407	10.000	11.436	-6.803
P6XP10	2.653*	-0.287	-9.301	1.729	-4.602	-14.912	14.729	18.636	-2.644
P7XP8	2.188*	-2.000	2.997	27.691*	2.390	10.256	7.407	17.032	29.243
P7XP9	3.975*	-0.293	-0.815	9.142	7.838	7.892	8.696	16.803	20.695
P7XP10	5.426**	-1.327	4.102	34.177**	2.805	13.680	-23.333	8.059	0.731
P8XP9	2.660*	-0.972	0.077	8.447	8.046	10.302	21.466	29.466**	-2.002
P8XP10	4.593*	-1.119	-1.393	28.698***	3.462	10.465*	12.500	18.919	30.901*
P9XP10	1.117	-1.492	1.052	-15.624*	6.210	10.156	16.123	22.910	-2.136
Average	**0.909**	**-1.706***	**0.099**	**16.627*****	**4.256***	**2.649**	**4.573**	**17.115*****	**13.906*****

Table.3 Estimates of inbreeding depression

	Spike Length E1	Spike Length E2	Spike Length E3	Grains/ Spike E1	Grains/ Spike E2	Grains/ Spike E3	1000-grain Weight (g) E1	1000-grain Weight (g) E2	1000-grain Weight (g) E3
P1XP2	-6.733	16.686	-21.949*	5.100	2.918	-13.777	2.030	7.383	16.086**
P1XP3	-21.846**	21.891	-19.501	1.480	1.607	-20.083*	1.736	4.909	22.558**
P1XP4	-19.412	12.519	-8.767	1.722	2.568	-9.479	4.535	6.484	19.922**
P1XP5	-5.640	19.243**	18.400	2.941	-1.994	-9.255	1.402	5.979	18.431*
P1XP6	-2.873	6.732	4.268	2.795*	1.714	-12.405	-0.094	7.189	16.424*
P1XP7	-2.083	15.968	6.859	5.729	2.554	-18.894*	2.813	7.745	14.387
P1XP8	-13.932*	19.524*	-0.811	36.808***	1.598	-7.713	2.268	7.007*	10.311*
P1XP9	-28.390	13.921	-9.971	-11.331**	2.382	-11.270**	5.391	8.384*	15.049**
P1XP10	-37.309**	4.488	4.744	-8.159*	-8.681**	-10.524	4.656	8.342	17.398**
P2XP3	-14.950	20.288*	15.671	0.041	1.476	-9.803	5.688	8.372	18.780**
P2XP4	-8.811	9.748	21.420**	-4.826	3.042	-8.296	2.440	9.998	18.298
P2XP5	-27.702	12.056	3.477	3.872**	2.385	-19.628**	5.167*	8.719	10.901
P2XP6	-28.079*	2.837	0.187	3.667	2.134	-8.912*	3.547	7.872	17.295
P2XP7	-7.447	7.309	11.830	11.440	2.090	-23.221**	7.941	8.448	22.991***
P2XP8	-31.011	-4.813	13.060	0.208	3.241	-8.347	-8.011	5.946	15.406*
P2XP9	-4.781	14.896	9.955	-1.459	1.545	-7.561	7.421	8.488	20.158*
P2XP10	-12.349	10.509	28.350*	-4.786	-2.625	-18.946***	3.436	9.921	15.321*
P3XP4	-4.647	2.856	-3.374	19.658***	0.962	-5.962	7.582	8.924	21.916*
P3XP5	1.509	6.592	-5.754	0.033	6.719	-10.034*	0.640	7.128*	15.431
P3XP6	-14.867	15.042	-7.598*	2.121	1.480	-5.519	4.429*	8.587*	16.321*
P3XP7	-17.713	15.816*	14.368	3.472	0.650	-11.316*	1.991	10.360	21.568*
P3XP8	-7.632	7.309	6.265	1.750	2.980	-9.880*	1.458	9.303	21.179*
P3XP9	1.464	13.067	13.723	2.150	2.708	-11.450	-2.076	6.444	16.011**
P3XP10	-34.179*	0.102	-14.587	1.935	1.408	-10.687**	1.894	9.222	25.023**
P4XP5	-15.793	10.842*	-6.996	3.842	2.130	-6.130	5.811	5.607	12.225**
P4XP6	10.617	-2.443	10.797	3.605*	2.472	-9.286	8.339***	7.201	18.190**
P4XP7	2.865	7.731	7.145	3.332	2.189	-9.351	1.048	6.039	15.769*
P4XP8	2.349	6.267	12.613	1.787	1.577	-9.138***	1.796	3.966	17.163
P4XP9	-21.450**	23.830**	8.798	1.998	3.519	-11.031*	3.225	8.945	18.061*
P4XP10	-47.558***	14.530	10.919*	2.088	3.841	-12.092*	2.167	8.617	17.832
P5XP6	-15.920*	14.244	11.271	2.277	1.729	-8.190*	3.986	2.580	25.689**
P5XP7	-16.183*	3.363	10.113	1.861	-5.542**	-5.024	2.552	4.639	18.972**
P5XP8	-25.321*	20.897*	23.830**	1.840	2.516	-8.682*	4.647	8.762*	12.643
P5XP9	-17.679	13.882	20.650	1.431	2.798	-8.488*	4.097	3.459	21.345**
P5XP10	-9.804	10.506	12.049	8.777**	-32.614***	-16.622*	1.024	9.598*	21.033*
P6XP7	-11.547	6.454	33.212**	1.750	3.038	-10.901*	7.230	4.866	19.159
P6XP8	11.398	18.070*	23.408*	3.960*	3.253	-5.493	3.757	5.421	18.412
P6XP9	-9.656	32.410*	21.252**	3.391	19.469**	-10.699**	0.909	7.764***	16.346
P6XP10	-7.887	21.300*	-31.840*	3.491	2.408	-17.038**	3.169	6.379*	24.097*
P7XP8	-24.727*	2.990	76.100***	2.080	-1.930	-10.720**	2.645	6.527	22.545**
P7XP9	13.282	14.262	28.045	3.708	3.637	-8.574*	6.506	8.227*	20.428**
P7XP10	3.670	-9.234	10.673*	2.207	0.620	-7.186	2.180	8.331*	16.577*
P8XP9	-48.992**	11.368*	15.776	1.763	3.584	-10.658**	2.320	12.499	17.886*
P8XP10	-6.554	16.147	6.220	1.385	1.503	-8.402	3.505	6.545*	14.090**
P9XP10	-21.177*	28.201*	21.858	2.137	2.524	-5.540	2.319	8.266	17.556**
Average	**-13.015*** **	**12.037*** **	**10.013*** **	**3.178***	**1.332**	**-10.217*** **	**3.181**	**7.391**	**17.957*** **

Table.4 Estimates of inbreeding depression

	Harvest Index (%) E1	Harvest Index (%) E2	Harvest Index (%) E3	Grain Yield/ Plant (g) E1	Grain Yield/ Plant (g) E2	Grain Yield/ Plant (g) E3
P1XP2	1.340	3.168	-7.945	-0.222	10.13	8.634
P1XP3	2.230	3.120	-6.937	5.994	22.07**	3.102
P1XP4	-4.229	2.055	-10.056	7.097	-7.4	-14.309
P1XP5	5.271	1.549	-6.888	1.944	13.85	10.711
P1XP6	3.994	3.067	-7.713	8.154	13.83*	10.021
P1XP7	0.849	12.906	-8.608	4.639	13.8	5.606
P1XP8	5.754	2.266	-4.317	3.052	18.34**	16.780
P1XP9	5.189	7.861	-12.067*	-1.637	30.59**	16.377
P1XP10	3.151	8.275	-8.715*	-7.004	23.09**	14.457**
P2XP3	-0.422	3.616	-11.445	17.026*	22.67**	22.737
P2XP4	4.308	4.489	-10.839*	9.540	14.55	17.089*
P2XP5	-3.397	9.599	-11.571	2.840	21.17*	14.313
P2XP6	-3.814	7.343	-7.808	12.150	22.88**	20.707
P2XP7	1.947	9.040	-11.466	10.020	20.44*	26.320*
P2XP8	-1.658	4.793	-9.037	-4.045	13.96	18.239*
P2XP9	0.094	21.385**	-11.899	14.875	28.27**	17.815
P2XP10	9.401	-3.962	-11.954	-1.704	14.86	14.032
P3XP4	0.879	23.767**	-6.989	9.944	20.62**	12.312
P3XP5	4.789	-20.958*	-8.226*	12.446	18.13	17.648**
P3XP6	7.115	26.315**	-14.448	3.371	13.12	13.624
P3XP7	-4.343	-1.841	-12.233*	-5.029	17.12*	22.134*
P3XP8	9.681	4.920	-10.087	-3.607	20.93**	17.697
P3XP9	6.735	3.755	-9.435	5.959	30.93**	16.424
P3XP10	-1.196	-3.249	-10.202*	-0.737	24.21**	16.754
P4XP5	-6.501	-4.656	-8.455	3.509	14.94	22.942
P4XP6	3.964	27.338***	-0.069	2.859	14.35*	18.374
P4XP7	1.664	7.450	-12.890*	4.176	7.3	14.300
P4XP8	-4.163	-15.907*	-11.788*	8.919	11.17	11.164
P4XP9	5.816	-14.050	-8.973	5.017	19.1*	10.532
P4XP10	11.772*	9.392	-10.309*	6.229	15.7	5.432
P5XP6	5.550	1.549	-10.704*	5.198	24.79**	12.495
P5XP7	5.386	15.453**	-11.860*	-0.632	3.73	15.199
P5XP8	8.845**	-11.261*	-17.996*	4.969	29.26**	16.388*
P5XP9	8.042*	15.126**	-10.272	4.744	17.49**	15.357*
P5XP10	3.623	0.273	-9.086	0.441	11.79	28.010*
P6XP7	3.742	8.259	-10.465	0.000	18.15*	18.599
P6XP8	1.500	1.544	-3.695	10.920	16.46	22.946
P6XP9	5.092	17.733**	-8.223	6.623	18.34*	17.441
P6XP10	8.035	-13.836	-6.613*	9.998	16.1	-25.012*
P7XP8	3.966	34.541**	-4.532	2.094	9.72	47.290**
P7XP9	-0.740	-27.234*	-14.127**	8.511	17.82*	-8.964
P7XP10	7.639	7.444	-16.321	8.633	5.97	18.600*
P8XP9	-5.438	-11.047*	-9.722	-0.559	11.49	18.387
P8XP10	3.055	10.022*	-11.511*	-2.837	9.97	18.199
P9XP10	3.540	2.601	-15.499*	-3.023	20.99**	19.118*
Average	**3.175**	**4.847*** **	**-9.924*** **	**4.243***	**17.978*** **	**14.967*** **

Each cross exhibited significant inbreeding depression for at least one or more traits in one or more traits, however none of the cross exhibited consistency for each character over each environment. For example the cross Raj 3765 X HD 2967 for days to heading in E_1 and E_2 environments and plant height in E_3 environment showed desirable significant inbreeding depression but in other cases it showed inbreeding depression either in desirable direction but non-significant or in undesirable direction. Cross Raj 3765 X DBW 621-50 for days to heading in E_2 environment, plant height in E_3 environment and spike length in E_3 environment showed desirable significant inbreeding depression but in other cases it also showed inbreeding depression either in desirable direction but non-significant or in undesirable direction. The same pattern was displayed by other crosses also for exhibition of inbreeding depression. Such results were also reported for different crosses and characters. However the cross HD 2967 X DBW 88 displyed desirable (significant negative) inbreeding depression for grain yield per plant and some other traits viz. spike length (cm) and number of grains per spike. Similar findings were also reported by Sharma and Menon (1996), Joshi *et. al.* (2003b), Prakash Ved and Joshi (2003), Singh *et. al.* (2004), Singh *et al.*, (2012), Kumar and Kerkhi (2014), Kumar *et al.*, (2015), Bhardwaj (2017) and Yadav 2017).

The negative inbreeding depression may result from the advantage of population buffering, which may occur in F2 generation due to the segregation of genes or sometimes because of formation of superior gene combinations, such a situation is valuable in conventional breeding programme.

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