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Shubham Yadav
NNPG, Department of Horticulture, Dr. RMLAU, Ayodhya, Uttar Pradesh, India

VP Pandey
Department of Vegetable Science, NDUA & T Kumarganj, Ayodhya, Uttar Pradesh, India

Rohit Maurya
Department of Vegetable Science, NDUA & T Kumarganj, Ayodhya, Uttar Pradesh, India

Sriom
Department of Vegetable Science, NDUA & T Kumarganj, Ayodhya, Uttar Pradesh, India

Samiksha
Department of Horticulture BBAU, Lucknow, Uttar Pradesh, India

Correspondence
Shubham Yadav
NNPG, Department of Horticulture, Dr. RMLAU, Ayodhya, Uttar Pradesh, India

Genetic studies on variability and genetic advance in garlic *(Allium sativum* L.)

Shubham Yadav, VP Pandey, Rohit Maurya, Sriom and Samiksha

Abstract
The present investigation entitled "Genetic studies on variability and character association in garlic *(Allium sativum* L.)". The experiment was executed at Main Experiment, Station of Department of Vegetable Science, NNPG Collage Goda Ayodhya UP during *Rabi* season 2015-2016, with following objectives (1) To study genetic variability available in different genotypes, (2) to estimate heritability and genetic advance in percent of mean. The experimental material for the present study consisted of eighty genotypes, with plot size of 2.0 × 0.60 m^2 with distance of 30 cm row to row and 10 cm plant to plant. Observation were recorded on plant height (cm), number of leaves per plant, length of leaf (cm), width of leaf (cm), neck thickness of bulb (cm), diameter of bulb (cm), bulb yield per plant (g), number of cloves per bulb, length of clove (cm), weight of clove (g), diameter of clove (cm) and total soluble solids (%).
Analysis of variance for design of experiment revealed that there is significant differences among both blocks and checks. Based on mean performance of genotypes, the NDG-9, NDG-41, NDG-45, NDG-18 and NDG-22 were identified as most promising genotypes for bulb yield per plant and other important traits. High heritability coupled with high genetic advance in percent of mean was recorded for number of cloves per bulb, length of leaf, T.S.S., width of clove and bulb yield per plant. The maximum positive direct effect on bulb yield per plant was exerted by number of cloves per bulb, weight of clove, total soluble solids, neck thickness of bulb, width of leaf and number of leaves per plant. It is suggested that selection for these traits will directly increase bulb yield per plant. The maximum inter-cluster distance was observed between cluster I and cluster IV which suggested that members of these two clusters are genetically very diverse to each other. The level of variation found in the genotypes showed great potentiality for improvement of garlic.

Keywords: Variability, genetic advance, garlic

Introduction
Garlic (*Allium sativum* L.) having diploid chromosome number 2n=2x=16 belongs to the family Amary llidaceae (Alliaceae); known as Lahsun in Hindi, is one of the important bulb crop grown in India. It has long been recognized as a valuable spice and condiments in India. It is a frost hardy bulbous, erect annual herb with narrow flat leaves and bears small white flowers and bulbils (Janick, 1979) [1]. Garlic is a scapigerous foeti perennial medicinal herb with underground compound bulbs covered by outer white thin scales with simple smooth round stem surrounded by the bottom by tublar leaf sheath. The leaves are simple, long, flat and linear. The flowers are small and white, arranged in round umbels mixed with small bulbils. The entire umbels are enclosed in a tear-drop shaped membranous spathe. Flowers are usually sterile. The seed stalk bears terminal inflorescence, which in terms bear bulbils instead of flowers. The shoot of garlic become flat and finally aborts after the development of bulbils in the inflorescence (Kothari and Shah, 1974) [3]. A compound bulb consists of smaller bulbils or a segment called "cloves" which are formed from auxiliary bulbs of the young foliage leaves and is surrounded by a thin white or pinkish papery sheath.

Material and method
The present investigation entitled "Studies on genetic variability and character association in garlic (*Allium sativum* L.)" was carried out at the Main Experiment Station, Department of Vegetable Science, NNPG Collage Faizabad (U.P.), India during *Rabi* 2015-16.
The experimental material of garlic used in the present study were, the collections from different places of Uttar Pradesh. Eighty genotypes have been used in the present study.
The experiment was laid out in a augmented block design with 80 entries and 7 blocks. The experimental field was prepared by harrowing and three cross ploughing with cultivator followed by planking. The field was well manure with FYM @ 30 tonnes per hectare 15 days before sowing. The irrigation channel was made between two blocks. Two rows of 2.0m x 0.60m plot with the distance of 30 cm row to row and 10 cm plant to plant was maintained.

The genotypes numbering eighty were sown in the blocks. The clove of each genotype was sown on *November18*, 2015. The first irrigation was done in just after sowing than irrigation was done at 15 days interval during crop growth. The recommended cultural practices and plant protection measures were applied to raise a healthy crop.

Result and Discussion

The result of analysis of variance for Augmented Design was carried out for thirteen characters and the results obtained are presented in table-1.

The variation due to the blocks were significant for all the characters and variance due to checks were also highly significant for all the characters like plant height (2.77 cm), number of leaves per plant (1.07), length of leaf (18.93 cm), width of leaf (0.17 cm), diameter of bulb (0.28 cm), neck thickness of bulb (0.157 cm), number of cloves per bulb (65.8), bulb yield per plant (20.13 g), length of clove (0.307 cm), weight of clove (0.14 g), diameter of clove (0.28 cm) and TSS (12.03 %).

Table 1: Analysis of variance (Augmented design) for 12 characters in garlic germplasm.

Characters	Sources of variation		
	Blocks	Check	Error
	6 (d.f)	2 (d.f)	12
Plant height (cm)	364.70**	2.77	36.68
Number of leaves per plant	3.77**	1.07*	0.24
Length of leaf (cm)	42.35**	18.93**	2.10
Width of leaf (cm)	0.58**	0.17*	0.03
Diameter of Bulb (cm)	0.97**	0.28*	0.06
Neck Thickness of Bulb (cm)	0.02	0.15*	0.02
Bulb Yield per plant (g)	3.69	20.13**	1.35
Number of cloves per Bulb	34.29**	65.80**	0.91
Length of Clove (cm)	0.16	0.30*	0.07
Weight of clove (gm)	0.07**	0.14**	0.01
Diameter of Clove (cm)	0.05	0.28**	0.03
Total Soluble Solids (%)	9.45**	12.03**	0.88

*,** Significant at 5% and 1% probability level, respectively

Eighty genotypes of garlic including four checks namely G-41, G-50, and G-282 were evaluated for various traits and there mean performance is described here under the table-2.

The data pertaining to this trait revealed that maximum plant height was observed in NDG-67 (71.55 cm). The minimum plant height was observed in NDG-37 (38.29 cm) against the general mean of (58.26 cm).

The number of leaves per plant ranged from 5.10 to 9.61, the maximum leaves per plant was recorded in NDG-47 (9.61) followed by NDG-43 (9.51) and NDG-42 (9.52), while the minimum leaves in NDG-29 (5.10) against the general mean of (7.93).

Length of leaf exhibited sufficient variability ranged from 22.94 cm to 42.37 cm. The maximum length of leaf was recorded in NDG-13 (42.37 cm) followed by NDG-2 (42.36 cm) and NDG-12 (39.9 cm), while the minimum leaf length in NDG-43 (22.94 cm) against the general mean of (32.82 cm).

The maximum width of leaf was recorded in NDG-19 (3.15 cm) followed by NDG-30(2.97 cm), while minimum in NDG-37 (0.71 cm) against the general mean (1.73 cm).

The diameter of bulb ranged from 2.38 cm to 4.60 cm against the general mean of 3.77 cm. The maximum diameter of bulb was recorded in NDG-22 (4.60 cm) followed by NDG-18 (4.59 cm), NDG-2 (4.44 cm), NDG-3 (4.42 cm), NDG-1 (4.35 cm) and NDG-10 (4.35 cm). The minimum diameter of bulb was observed in NDG-39 (2.38 cm).

The maximum neck thickness of bulb was recorded in NDG-27 (2.15 cm). The mean value of neck thickness of bulb ranged from 0.95 cm to 2.15 cm against the general mean of 1.50 cm. The minimum neck thickness of bulb was recorded in NDG-37 (0.95 cm).

The maximum bulb yield per plant was observed in NDG-9 (28.91 g) followed by NDG-41 (27.98 g) and NDG-45 (27.94 g) against the general mean 22.92 g. While the minimum bulb yield per plant was recorded in NDG-31 (16.26 g).

The minimum and maximum value for number of cloves per bulb ranged from 14.46 to 27.89 against the general mean of 21.04 The maximum number of cloves per bulb was recorded in NDG-22 (27.89) followed by NDG-42(26.67), NDG-2 (26.56) and NDG-51 (25.89),while minimum cloves per bulb was recorded in NDG-31 (14.46).

The maximum length of clove was recorded in NDG-23 (3.56 cm) followed by NDG-55 (3.29 cm), NDG-32 (2.96 cm), NDG-29 (2.89 cm) and NDG-30 (2.77 cm) against the general mean of 2.33 cm, while the minimum length of clove was recorded in NDG-35 (1.49 cm).

The minimum and maximum value of weight of clove ranged from 0.79 g to 2.47 g against the general mean of 1.28 g. The highest weight of clove was recorded in NDG-69 (2.47 g) followed by NDG-68 (2.17 g), NDG-39 (2.14 g), NDG-13 (2.04 g) and NDG-5 (1.98 g), while the lowest weight of clove was recorded in NDG-56 (0.79 g).

The mean value of diameter of clove ranged from 0.88 cm to 2.05 cm against the general mean 1.41 cm. The maximum diameter of clove was recorded in NDG-43 (2.05 cm) followed by NDG-34 (1.90 cm), NDG-2 (1.86 cm) and NDG-37 (1.85 cm), while the minimum diameter of clove was observed in NDG-48 (0.88 cm).

The large amount of variability was found for total soluble solids (TSS %) per cent. The mean value of TSS ranged from 28.92 to 42.26 per cent. The maximum TSS was recorded in NDG-49 (42.26%) followed by NDG-48 (40.43%), NDG-63 (40.37%), NDG-15 (40.24%) and NDG-50 (39.39%), the minimum TSS was recorded in NDG-9 (28.92%).

Table 2: Mean performance of 80 genotypes for 12 characters in garlic

S. No.	Characters/No. of Genotypes	Plant height (cm)	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Diameter of bulb (cm)	Neck Thickness of bulb (cm)	Bulb Yield per plant (g)	Number of Cloves per bulb	Length of Clove (cm)	Weight of Clove (g)	Diameter of Clove (cm)	T.S.S. (%)
1	NDG-1	68.269	8.736	34.236	0.983	4.359	1.148	24.841	20.956	2.379	1.174	1.383	36.860
2	NDG-2	68.669	8.946	42.366	1.003	4.449	1.268	25.901	26.566	2.609	1.274	1.863	37.080
3	NDG-3	68.869	6.376	39.316	0.823	4.429	1.498	22.801	20.786	2.589	1.084	1.263	35.930
4	NDG-4	65.399	7.836	36.656	1.233	3.549	1.508	21.761	19.546	2.569	1.094	1.453	34.660
5	NDG-5	54.149	8.006	28.706	0.843	4.319	1.148	25.861	24.936	2.609	1.984	1.803	33.890
6	NDG-6	52.389	6.376	33.186	1.023	4.319	1.258	24.631	23.736	2.529	1.774	1.513	29.840
7	NDG-7	63.979	7.926	38.346	1.983	4.059	1.598	22.901	19.876	2.239	1.574	1.603	31.850
8	NDG-8	59.279	8.206	34.206	1.153	3.979	1.288	24.851	24.886	2.449	1.104	1.503	30.860
9	NDG-9	48.469	6.776	31.146	0.903	3.849	1.468	28.911	22.956	2.199	1.164	1.823	28.920
10	NDG-10	65.529	7.796	36.346	1.343	4.359	1.378	21.571	24.646	2.609	1.294	1.613	35.120
11	NDG-11	54.099	8.006	34.216	1.493	4.239	1.198	18.701	16.956	2.549	1.514	1.503	33.280
12	NDG-12	62.629	7.980	39.929	2.043	3.709	1.631	22.198	16.900	2.409	1.240	1.773	38.390
13	NDG-13	65.369	7.570	42.379	2.533	4.439	1.671	19.038	20.220	2.469	2.040	1.393	34.920
14	NDG-14	59.859	8.300	36.789	2.403	4.499	1.411	26.098	25.060	2.219	1.260	1.593	33.290
15	NDG-15	60.059	8.380	39.319	1.673	3.869	1.161	21.738	16.790	2.199	1.470	1.773	40.240
16	NDG-16	62.309	9.090	36.869	2.413	4.239	1.371	22.308	15.960	1.959	1.190	1.323	29.230
17	NDG-17	62.919	8.190	33.199	2.513	4.319	1.551	20.158	20.300	2.119	1.160	0.993	33.700
18	NDG-18	66.789	8.510	35.039	2.803	4.459	1.721	27.848	21.000	2.269	1.180	1.753	32.880
19	NDG-19	68.019	7.980	35.849	3.153	3.949	1.411	26.498	22.110	2.629	1.130	1.013	36.970
20	NDG-20	69.849	9.610	36.059	2.533	3.989	1.571	23.438	22.020	2.329	1.250	1.083	34.100
21	NDG-21	63.329	7.360	38.299	1.773	4.419	1.281	23.008	21.780	2.389	1.240	1.203	32.060
22	NDG-22	71.279	8.380	37.489	1.343	4.609	1.171	27.748	27.890	2.549	1.220	0.963	35.530
23	NDG-23	69.452	9.593	36.649	1.760	3.752	1.611	18.264	25.800	3.562	1.064	1.720	36.110
24	NDG-24	61.862	8.983	31.319	2.070	4.072	1.941	26.774	19.070	2.852	1.264	1.350	36.540
25	NDG-25	70.062	7.353	37.259	2.210	3.932	2.001	22.264	23.760	2.752	1.444	1.040	39.270
26	NDG-26	54.562	8.573	29.469	2.400	3.342	1.431	26.264	16.070	2.812	1.044	1.320	34.500
27	NDG-27	56.602	7.353	30.529	1.930	3.732	2.151	20.264	15.600	2.772	1.884	2.030	37.330
28	NDG-28	47.752	6.733	26.619	2.290	3.772	1.891	20.974	17.170	2.252	1.074	1.210	36.920
29	NDG-29	41.052	5.103	26.039	2.250	4.092	1.631	19.034	15.340	2.892	1.094	1.790	33.050
30	NDG-30	42.932	6.943	26.859	2.970	2.892	1.401	20.324	17.640	2.772	1.204	1.460	34.070
31	NDG-31	39.052	7.553	28.079	1.380	3.282	1.381	16.264	14.460	2.362	1.134	1.640	35.900
32	NDG-32	47.012	8.163	28.699	1.440	3.422	1.271	26.264	20.070	2.962	1.064	1.420	35.700
33	NDG-33	53.332	6.943	31.389	1.310	2.422	1.501	25.264	24.650	2.402	1.484	1.300	36.720
34	NDG-34	51.812	6.453	32.939	1.100	3.106	1.318	22.311	17.363	1.819	1.154	1.900	33.960
35	NDG-35	51.412	6.243	34.569	1.180	3.736	1.278	24.821	15.913	1.499	1.414	1.480	32.540
36	NDG-36	45.902	7.473	28.249	1.070	2.696	1.728	20.161	20.423	1.779	1.104	1.280	36.620
37	NDG-37	38.292	5.433	26.309	0.710	2.836	0.958	16.761	14.673	1.699	1.434	1.850	34.980
38	NDG-38	52.282	6.853	37.629	1.140	2.616	1.538	22.311	20.673	2.279	1.154	1.440	32.540
39	NDG-39	46.062	7.063	29.469	1.120	2.386	1.568	21.861	15.673	2.469	2.144	1.590	34.780
40	NDG-40	54.872	9.303	30.699	1.520	3.966	1.498	20.181	20.673	1.839	1.184	1.790	36.100
41	NDG-41	62.422	9.513	27.819	1.520	4.126	1.408	27.981	22.673	2.519	1.794	1.630	35.390
42	NDG-42	52.022	9.513	27.839	1.650	3.876	1.288	23.221	26.673	2.439	1.184	1.490	36.000
43	NDG-43	46.022	9.513	22.949	1.380	3.596	0.968	25.031	25.473	2.519	1.094	2.050	33.350
44	NDG-44	55.492	8.283	25.599	1.460	3.346	1.208	19.311	18.673	2.399	1.114	1.350	38.660
45	NDG-45	56.446	7.986	29.689	1.957	3.746	1.594	27.941	20.403	2.052	1.060	1.020	38.173
46	NDG-46	63.176	7.576	32.749	2.097	3.926	1.234	25.561	23.653	2.252	1.350	1.800	36.743
47	NDG-47	60.936	9.616	36.219	2.607	4.276	2.014	24.531	21.313	2.072	0.960	1.350	40.433
48	NDG-48	64.806	7.166	39.889	1.977	4.186	1.634	23.521	23.593	1.662	1.080	0.880	39.193
49	NDG-49	65.016	9.006	32.849	2.357	4.206	1.904	25.931	23.153	2.192	1.030	1.460	42.263
50	NDG-50	56.796	8.596	27.999	1.827	3.786	1.434	22.501	24.183	2.452	0.950	1.320	39.393
51	NDG-51	48.306	7.166	25.199	1.567	4.006	1.164	27.041	25.893	2.052	1.000	1.110	36.133
52	NDG-52	55.016	9.006	24.379	1.727	3.616	1.364	27.601	21.113	1.862	1.160	1.190	33.073
53	NDG-53	46.206	8.596	25.199	2.017	3.376	1.184	26.401	21.813	1.602	1.140	1.000	36.433
54	NDG-54	55.256	9.406	30.559	1.957	4.166	0.984	18.971	14.783	2.052	1.280	1.460	35.113
55	NDG-55	60.316	9.406	34.849	2.417	3.616	1.294	22.971	23.153	3.292	0.990	1.110	39.393
56	NDG-56	67.542	6.670	38.589	1.890	3.326	1.711	21.991	24.446	2.245	0.794	1.450	36.493
57	NDG-57	63.052	8.710	31.659	1.870	3.826	1.931	23.221	20.826	1.935	0.814	1.560	32.613
58	NDG-58	67.332	9.320	32.879	2.110	4.076	1.551	22.931	21.596	2.325	0.874	1.760	37.313
59	NDG-59	56.222	7.890	27.559	1.870	3.626	1.631	20.421	20.816	1.895	1.114	1.280	31.773
60	NDG-60	55.912	7.890	28.799	2.170	2.906	1.711	18.931	20.466	1.915	0.994	1.150	34.253
61	NDG-61	67.942	9.320	32.489	1.910	3.926	1.791	23.221	19.466	1.935	1.424	1.450	33.843
62	NDG-62	53.662	8.100	25.499	1.760	3.866	1.441	24.031	24.046	2.045	1.484	1.070	37.313
63	NDG-63	57.132	8.300	35.739	1.820	3.686	1.931	24.851	21.896	2.085	1.384	1.240	40.373
64	NDG-64	64.562	6.060	33.699	1.800	3.726	1.801	19.241	18.786	1.955	0.994	1.240	35.473
65	NDG-65	67.132	7.890	31.039	1.990	4.096	1.991	17.241	22.316	2.105	0.794	1.360	39.143
66	NDG-66	55.912	7.690	28.129	1.640	2.906	1.951	22.431	18.826	1.795	0.824	1.250	39.353
67	NDG-67	71.559	9.223	36.869	1.777	4.152	1.798	19.864	18.003	2.425	1.954	1.056	38.186
68	NDG-68	66.249	8.613	34.829	1.717	3.032	1.658	23.214	22.593	2.505	2.174	1.416	33.836

69	NDG-69	67.269	7.593	35.239	1.737	3.602	1.418	25.534	23.673	2.445	2.474	1.046	34.716
70	NDG-70	68.909	6.773	34.619	1.577	3.522	1.378	20.964	21.073	2.525	1.554	1.216	38.796
71	NDG-71	70.739	8.003	35.439	1.907	3.822	1.358	23.334	22.593	2.485	1.154	1.296	35.736
72	NDG-72	66.249	6.773	32.379	1.557	4.212	1.208	18.314	20.163	2.445	1.664	1.696	30.236
73	NDG-73	60.949	7.793	31.359	1.537	3.412	1.678	21.524	21.023	2.255	1.474	1.476	37.376
74	NDG-74	58.709	8.003	28.709	1.457	3.132	1.548	24.134	24.683	2.225	1.264	1.086	37.376
75	NDG-75	40.809	7.593	31.359	1.457	4.132	1.768	23.224	23.933	2.355	1.204	1.296	34.106
76	NDG-76	44.479	6.983	35.909	1.517	4.272	1.828	20.854	22.493	2.745	1.154	1.436	34.316
77	NDG-77	39.219	7.793	33.559	1.337	3.992	1.678	22.544	22.203	2.195	1.374	1.306	30.836
78	G-41	57.751	7.351	35.714	1.656	3.793	1.177	24.687	22.399	2.960	1.404	1.279	35.807
79	G-50	58.947	8.113	38.760	1.400	3.406	1.350	23.991	21.009	2.541	1.161	1.676	38.110
80	G-282	58.689	7.574	38.313	1.364	3.509	1.476	21.464	16.531	2.764	1.156	1.414	35.871
	Mean	58.262	7.935	32.820	1.739	3.778	1.503	22.923	21.041	2.339	1.283	1.419	35.502
	Std. Dev.	8.783	1.012	4.540	0.513	0.508	0.269	2.901	3.198	0.372	0.328	0.271	2.751
	Std. Error	0.982	0.113	0.508	0.057	0.057	0.030	0.324	0.358	0.042	0.037	0.030	0.308
	C. V. %	15.074	12.755	13.833	29.495	13.450	17.879	12.657	15.199	15.884	25.557	19.072	7.749
	Lowest	38.292	5.103	22.949	0.710	2.386	0.958	16.264	14.460	1.499	0.794	0.880	28.920
	Highest	71.559	9.616	42.379	3.153	4.609	2.151	28.911	27.890	3.562	2.474	2.050	42.263

An insight into the magnitude of variability exists in a crop species of most importance, as it provides the basis of the effective selection. In general, the phenotypic coefficient of variability was higher than genotypic coefficient of variability for all the twelve characters under study which indicates that environment played a considerable role in the expression of their traits. The range of variability of different traits alone does not allow a decision as to which character was showing the highest degree of variability. Therefore, accurate relative comparison can be made with the help of phenotypic and genotypic coefficient of variation. Phenotypic variation was partitioned into genotypic and environmental component.

The significant differences were observed among genotypes for all the characters studied. The higher magnitude of coefficient of variation at phenotypic as well as genotypic levels observed for width of leaf, weight of clove, number of cloves per bulb, suggesting additive gene action. Similar results were reported by Lopez- Frasca *et al*. (1997) [4], Korala *et al*. (1981) [5], Mehta and Patel (1985) [6], Agrawal and Tiwari (2004) [7], Khar *et al*. (2005) [2].

Moderate coefficient of variation at phenotypic as well as genotypic level observed in case of number of leaves per plant, Plant height, length of leaf, diameter of bulb, Bulb yield per plant and diameter of clove. Similar results were reported by Mohanty (2001) [9] in onion. While lowest GCV and PCV was observed for total soluble solids (TSS). Similar results were reported by Agrawal and Tiwari (2004) [7]. Moderate to low variation exerted for these traits revealed that there is a reasonable scope for improvement in these traits.

Heritability in broad sense of a character is important to the breeder since it indicates the possibility and extent to which improvement is possible through selection. It also indicates direction of selection pressure to be applied for the traits during selection because it measures relationship between parent and their progeny, widely used in determining the degree to which a character may be transmitted from parent to offspring. However, high heritability alone is not enough to make efficient selection in advanced generation unless accompanied by substantial amount of genetic advance (Burton and De-Vane, 1953).

The genetic advance is commonly predicted as a product of heritability ratio and selection differentials. Panse (1967) [10] mentioned that where high heritability value is accompanied by high genetic advance. The progress realized by selection would be most appropriate.

In the present investigation, high heritability coupled with high genetic advance as per cent of mean was observed for number clove per bulb, length of leaf, total soluble solids, width of clove, and bulb yield per plant. This indicates that these traits were less influenced by environment. Similar results were reported by Mehta and Patel (1985) [11], Singh and Chand (2004) [12], Singh (1981) [13], Kohali (2001), Doruchowaski (1986) [15] and Khar *et al.* (2005) [8]. Whereas, high heritability coupled with moderate genetic advance observed for diameter of bulb and bulb yield per plant and moderate heritability coupled with moderate genetic advance is observed for number of leaves per plant and plant height. While total soluble solids (TSS) showed lowest heritability. Similar results were reported by Agrawal and Tiwari (2004) [7].

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