

Variability and selection parameters for yield and yield-contributing traits in garlic (*Allium sativum*)*

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Received: 3 August 2009; Accepted: 20 May 2010

Key words: *Allium sativum*, Correlation, Garlic, Genetic advance, Heritability, Variability

Garlic (*Allium sativum* L.) has higher nutritive value than the other bulb crops and has good export potential as fresh bulb as well as in the form of dehydrated product (Gupta and Singh 1998). The average productivity of garlic in India is 5 tonnes/ha, which is quite low as compared to other garlic growing countries. To meet out the domestic requirement and fulfill the export demand, selection of suitable variety for growing under different agro-climatic condition is necessary. As this crop is propagated vegetatively, the clonal selection is the important breeding method. Yield being a complex quantitative trait depends on the number of attributes. With a view to develop high-yielding garlic variety the National Horticultural Research and Development Foundation, Nashik collected a good numbers of germplasms from different part of the country and conducted field experiment to assess the genetic diversity of local collection or landraces based on morphological and physiological variation to evaluate these relationship and potential for genetic resources to identify clones having high bulb yield with large sized cloves, less number of cloves/bulb and other desirable traits.

The experiment was carried out at National Horticultural Research and Development Foundation, Salaru, Karnal during 2005–07. The 19 divers' germplasms along with 4 checks, viz 'G 1', 'G 41', 'G 50' and 'G 282' were used, selected from more than 300 collected germplasms from different region (Table 1). The experiment was laid out in randomized block design with 3 replications. Cloves were selected uniform in size and planted in first fortnight of October in 3.0 m × 1.5 m bed at a spacing of 15 cm × 7.5 cm. The climate of Karnal is subtropical with minimum and maximum temperature ranging between 5° and 35°C and

favourable for garlic cultivation. All cultural operations were uniformly followed to ensure a healthy crop growth and development. Harvesting was done as per the maturity of different advance lines. The observations were recorded on ten randomly selected plants in each replications for all the characters, viz plant height (cm), leaves/plant, neck thickness (cm), bulb diameter (cm), bulb size index (cm²), weight of 20 bulbs (g), clove diameter (cm), clove size index (cm²), cloves per bulbs, weight of 50 cloves (g), bolters (%), total soluble solid (%), dry matter (%), days for bulb initiation, days for harvesting, gross yield (tonnes/ha) and marketable yield (tonnes/ha).

The pooled data of both years were analyzed statistically as suggested for genotypic and phenotypic coefficients of variations by Burton and Devane (1958). Heritability in broad sense and expected genetic advance as per cent of mean was worked out with method suggested by Johnson *et al.* (1955) and correlations were worked out by the method of Al-Jibouri *et al.* (1958).

All the characters showed significant variances, indicating sufficient diversity among the germplasms (Table 1). A wide range of variability was recorded for marketable yield (8.12 to 16.92 tonnes/ha), gross yield (11.72 to 20.15 tonnes/ha), bolters (5.16 to 26.42%), weight of 50 cloves (36.83 to 97.50 g), cloves/bulb (17.0 to 46.33), weight of 20 bulbs (453.33 to 700.0 g), plant height (83.80 to 96.96 cm) and clove size index (0.833–1.75 cm²). These high ranges of variation among different advance lines could be utilized by plant breeder for the improvement of desired traits.

The mean data indicated that the maximum gross yield (20.15 tonnes/ha) and marketable yield (16.92 tonnes/ha) was recorded for advance line 'G 189' followed by 'G 324' (19.38 tonnes/ha) and (16.48 tonnes/ha), respectively. The maximum 20 bulbs weight (700.0 g) and weight of 50 cloves (97.50 g) was observed for check 'G 282'.

Minimum days for bulb initiation (61.66 days) and days to harvesting (149.83 days) was however, taken by check 'G

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Table 1 Mean values for different advance lines of garlic for some quantitative characters

Advance line	Plant height (cm)	Leaves/plant (cm)	Neck thickness (cm)	Bulb diameter (cm)	Bulb Size Index (cm ²)	Weight of 20 bulbs (kg)	Clove diameter (cm)	Clove size index (cm ²)	Cloves/bulb (g)	Weight of 50 cloves (g)	Bolters (%)	TSS (%)	Dry matter (%)	Days for bulb initiation	Days for harvesting (tonnes/ha)	Gross yield (tonnes/ha)	Marketable yield (tonnes/ha)
'G 4'	88.55	7.46	1.44	4.44	15.00	556.66	0.916	2.42	41.66	40.50	18.56	38.08	40.18	66.66	159.66	16.74	13.81
'G 176'	91.06	7.16	1.52	4.47	14.18	613.33	0.983	2.45	41.66	39.66	19.56	37.51	39.27	69.66	159.50	17.24	14.89
'G 189'	92.70	7.46	1.51	4.74	16.50	698.33	0.833	2.36	43.50	49.83	18.46	39.73	41.76	68.66	159.83	20.15	16.92
'G 192'	92.95	7.00	1.54	4.63	13.57	676.66	1.060	2.74	46.33	37.33	26.42	37.33	39.43	61.66	160.50	18.00	15.21
'G 200'	93.66	6.93	1.51	4.45	14.16	665.00	1.100	2.79	38.66	38.00	21.33	39.58	41.63	70.00	162.50	17.64	14.50
'G 222'	91.43	6.93	1.44	4.62	14.40	520.00	1.100	2.46	38.33	50.33	15.48	39.72	41.94	68.23	158.33	17.49	13.61
'G 255'	95.46	7.50	1.54	4.98	15.21	673.33	1.100	2.75	40.66	38.00	22.32	39.70	41.68	62.00	159.83	16.64	13.98
'G 264'	92.85	7.66	1.49	4.41	13.86	586.66	1.050	2.34	38.33	36.83	23.91	38.16	40.31	63.00	158.66	17.44	14.65
'G 302'	87.33	7.60	1.50	4.70	13.86	620.00	1.180	3.06	25.66	59.66	11.38	34.96	36.82	67.00	151.66	11.72	8.12
'G 304'	93.44	6.66	1.48	4.61	14.67	636.66	1.060	2.48	40.16	46.00	24.31	35.51	37.59	62.23	158.33	16.76	13.28
'G 305'	83.80	6.76	1.52	4.09	13.32	453.33	1.250	2.67	30.66	62.00	5.16	40.23	42.20	69.33	158.66	12.65	10.90
'G 324'	95.83	6.93	1.49	4.95	16.49	683.33	1.160	3.15	41.66	53.83	29.20	39.00	41.00	62.66	158.16	19.38	16.48
'G 366'	92.91	7.40	1.47	4.55	14.20	543.33	1.180	3.13	33.33	52.83	10.43	35.50	37.69	69.33	161.50	15.01	11.00
'G 368'	91.50	7.66	1.53	4.47	13.99	530.00	1.250	3.09	32.00	51.50	12.16	36.13	38.32	68.33	157.83	13.38	9.99
'G 369'	93.75	7.20	1.42	4.40	13.91	548.33	1.210	3.14	31.66	53.66	12.15	35.75	38.06	67.00	156.16	13.85	9.76
'G 1(C)'	96.96	6.86	1.49	4.98	15.11	640.00	1.010	2.36	41.00	47.50	16.43	39.96	42.28	62.33	157.16	18.04	15.00
'G41(C)'	93.80	7.26	1.43	4.19	13.79	573.33	1.030	2.78	37.16	39.66	12.85	37.38	39.53	66.66	156.33	13.82	10.59
'G50(C)'	86.73	7.19	1.44	4.79	16.17	626.66	1.100	2.79	39.00	41.16	15.89	38.65	40.96	62.00	157.16	17.25	14.67
'G282(C)'	93.05	7.13	1.45	4.71	16.08	700.00	1.750	4.43	17.00	97.50	15.25	35.62	38.06	61.66	149.83	15.96	12.24
Range	83.80–96.96	6.66–7.66	1.42–1.54	4.09–4.98	13.32–16.50	453.33–700	0.833–1.75	2.34–4.43	17.0–46.33	36.83–97.5	5.16–26.42	34.96–39.96	36.82–42.28	61.66–70.00	149.83–162.5	11.72–20.15	8.12–16.92
S Em±	1.700	0.130	0.017	0.060	0.146	15.060	0.041	0.042	1.500	1.920	0.930	0.410	0.442	0.500	4.790	4.790	3.330

282'. The highest total soluble solid (39.96%) and dry matter (42.38%) was noted for check 'G 1' followed by 'G 189' (39.73%) and (41.63%), respectively. It is concluded from mean data that advance lines 'G 189' and 'G 324' can be used in garlic crop improvement programme.

The extent of variability with respect to 17 quantitative characters in different advance lines of garlic measured in terms of range, genotypic coefficient of variations (GCV), phenotypic coefficient of variations(PCV), environment coefficient of variations along with heritability (h^2), genetic advance and genetic advances as per cent of mean are presented in Table 2. All the characters showed considerable variations. In the present investigation phenotypic coefficient of variations was higher than the GCV for all the traits, indicating environmental factors influenced their expression. The GCV and PCV were high for bolter (%), weight of 50 cloves, cloves/bulb, marketable yield, clove size index, clove diameter and gross yield. Remaining traits had low genotypic and phenotypic coefficient of variations. Similar results in some important traits are reported by Godhani and Singh (2000). Wide difference between phenotypic and genotypic coefficient of variations indicated their susceptibility to environmental fluctuations and narrow difference showed less environmental interference on the expression of these traits. The traits which showed high phenotypic and genotypic coefficient of variations are of economic importance and there is scope for improvement of these traits through selection.

The heritability in broad sense ranged from 47.76 to 97.78%. High value of heritability was recorded for clove

size index (97.78%), followed by marketable yield (94.61%), weight of 50 cloves (94.56%), days for bulb initiation (94.46%), bulb size index (93.94%), bolters (93.40%), days for harvesting (92.19%) and gross yield (87.85%). Remaining all characters showed moderate heritability. High heritability for above characters clarified that they were least affected by environmental modifications and selection based on phenotypic performance would be reliable. The findings are in consonance with observation of Mehta and Patel (1985).

The heritability estimates along with genetic advance are more useful than the heritability values alone for selecting the best individual. From the present investigation, the genetic advance as per cent of mean ranged from 3.24 to 69.30. High estimates of genetic advance was showed by bolter (69.30%), followed by weight of 50 cloves (56.54%), marketable yield (36.92%), cloves/bulb (35.69%), clove size index (34.87%), clove diameter (30.35%) and rest of the traits showed moderate to low genetic advance. High values of heritability, GCV and genetic advance as per cent of mean were observed for bolters, weight of 50 cloves, marketable yield, cloves per bulb, clove size index, clove diameter and weight of 20 bulbs, suggesting that all these traits are genetically controlled by additive gene action (Panse 1957); and can be improved through mass selection, family selection and other modified selection. High heritability coupled with low genetic advance as per cent of mean with low GCV were observed for all the traits. It is suggested that these traits were governed by non-additive gene action and high genotype-environment interaction.

Table 2 Range, mean, coefficient of variation, heritability and genetic advance for different traits in garlic

Character	Range	G. Mean	Coefficient of variation			Heritability (%)	Genetic advance	GA as per cent of mean
			PCV (%)	GCV (%)	ECV (%)			
Plant height (cm)	83.80–96.96	91.98	4.450	3.070	3.210	47.760	4.020	4.370
Leaves/plant	6.66–7.66	7.17	4.820	3.550	3.260	54.260	0.380	5.290
Neck thickness (cm)	1.42–1.54	1.48	3.000	2.170	2.060	52.640	0.048	3.240
Bulb diameter	4.09–4.98	4.58	5.520	5.030	2.270	83.040	0.430	9.380
Bulb size index (cm ²)	13.32–16.5	14.66	7.040	6.830	1.730	93.940	1.990	13.570
Weight of 20 bulbs (kg)	453.33–700	607.63	11.940	11.140	4.290	87.070	130.210	21.420
Clove diameter (cm)	0.833–1.75	1.12	17.330	16.120	6.350	86.560	0.340	30.350
Clove size index (cm ²)	2.34–4.43	2.81	17.410	17.210	2.580	97.780	0.980	34.870
Cloves/bulb	17.0–46.33	36.76	19.870	18.550	7.100	87.200	13.120	35.690
Weight of 50 cloves (g)	36.83–97.50	49.25	29.030	28.230	6.770	94.560	27.850	56.540
Bolters (%)	5.16–26.42	17.43	36.030	34.820	9.250	93.400	12.080	69.300
Total soluble solid (%)	34.96–39.96	37.82	4.980	4.610	1.900	85.380	3.310	8.750
Dry matter (%)	36.82–42.28	39.93	4.720	4.310	1.910	83.530	3.240	8.110
Days for bulb initiation	61.66–70.00	65.71	5.000	4.860	1.170	94.460	6.400	9.730
Days for harvesting	149.83–162.50	158	1.970	1.890	0.550	92.190	5.930	3.750
Gross yield (tonnes/ha)	11.72–20.15	16.27	14.650	13.730	5.100	87.850	43.150	26.510
Marketable yield (tonnes/ha)	8.12–16.92	13.14	18.940	18.420	4.390	94.610	48.520	36.920

PCV, Phenotypic coefficient of variation; GCV, genotypic coefficient of variation; ECV, environmental coefficient of variation; GA, genetic advance

Table 3 Genotypic (G), and Phenotypic (P) correlation coefficient for different characters in garlic

Characters	Plant height (cm)	Leaves/plant (cm)	Neck thickness (cm)	Bulb diameter (cm)	Bulb size index (cm ²)	Weight of 20 bulbs (kg)	Clove diameter (cm)	Clove size index (cm ²)	Clove/bulb	Weight of 50 cloves (g)	Bolters (%)	TSS (%)	Dry matter (%)	Days for bulb initiation	Days for harvesting	Gross yield (tonnes/ha)	Marketable yield (tonnes/ha)
Plant height	G 1.00	-0.095	-0.008	0.507**	0.286	0.564**	-0.085	0.071	0.382	-0.136	0.680**	-0.028	0.002	-0.398	0.179	0.504**	0.402*
	P 1.00	-0.045	0.028	0.396	0.194	0.486*	-0.009	0.067	0.144	-0.112	0.365	0.078	0.091	-0.281	0.093	0.446*	0.291
Leaves/plant	G	1.000	-0.144	0.020	0.035	0.075	-0.187	-0.005	-0.119	-0.138	-0.064	-0.163	-0.179	0.068	-0.167	-0.105	-0.159
	P	1.000	-0.087	0.025	0.076	0.087	-0.172	-0.017	-0.036	-0.126	-0.042	-0.206	-0.216	0.033	-0.059	-0.088	-0.072
Neck thickness	G	1.000	1.000	0.170	-0.171	0.274	-0.146	-0.201	0.217	-0.183	0.287	0.264	0.200	0.043	0.395	0.112	0.233
	P	1.000	1.000	0.078	-0.135	0.193	-0.083	-0.149	0.165	-0.171	0.211	0.199	0.155	0.003	0.228	0.057	0.176
Bulb diameter	G	1.000	1.000	0.733**	0.717**	0.717**	-0.012	0.103	0.211	0.083	0.508*	0.147	0.164	-0.604**	-0.143	0.565**	0.448*
	P	1.000	1.000	0.680**	0.678**	0.678**	-0.008	0.088	0.169	0.068	0.420*	0.138	0.143	-0.528**	-0.116	0.537**	0.477*
Bulb size index	G	1.000	1.000	1.000	0.633**	0.633**	0.052	0.215	0.101	0.265	0.368	0.373	0.302	-0.418*	-0.166	0.636**	0.570**
	P	1.000	1.000	1.000	0.598**	0.598**	0.029	0.190	0.089	0.232	0.319	0.205	0.217	-0.338	-0.144	0.584**	0.572**
Weight of 20 bulbs	G	1.000	1.000	1.000	1.000	1.000	-0.008	0.206	0.228	0.044	0.719**	0.027	0.028	-0.558**	-0.118	0.617**	0.574**
	P	1.000	1.000	1.000	1.000	1.000	0.024	0.193	0.152	0.036	0.611**	0.064	0.054	-0.508**	-0.073	0.619**	0.559**
Clove diameter	G	1.000	1.000	1.000	0.936**	0.887**	1.000	0.936**	-0.887**	0.872**	-0.303	-0.461*	-0.425*	-0.213	-0.673**	-0.439*	-0.451*
	P	1.000	1.000	1.000	0.880**	-0.881**	1.000	0.880**	-0.881**	0.817**	-0.293	-0.335	-0.301	-0.175	-0.606**	-0.342	-0.429*
Clove size index (cm ²)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.819**	0.812**	-0.219	-0.544**	-0.514**	-0.182	-0.647**	-0.330	-0.399
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.736**	0.808**	-0.196	-0.463*	-0.426*	-0.184	-0.618**	-0.296	-0.387
Cloves/bulb	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.889**	0.612**	0.557**	0.533**	-0.094	0.794**	0.722**	0.732**
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.766**	0.619**	0.456*	0.435*	-0.091	0.709**	0.577**	0.684**
Weight of 50 cloves (g)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.412*	0.365	-0.339	-0.066	-0.746**	-0.308	-0.358
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.362	-0.294	-0.261	-0.063	-0.703**	-0.271	-0.344
Bolters (%)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.196	0.178	-0.546**	0.343	0.806**	0.766**
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.167	0.156	-0.518**	0.305	0.683**	0.713**
TSS (%)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998**	0.033	0.477*	0.516**	0.659**
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.992**	0.023	0.407*	0.513**	0.568**
Dry matter (%)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.003	0.456*	0.524**	0.661**
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-0.008	0.380	0.517**	0.557**
Days for bulb initiation	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.305	-0.357	-0.330
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.282	-0.299	-0.313
Days for harvesting	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.446*	0.480*
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.401*	0.467*
Gross yield (tonnes/ha)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998**
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.916**
Marketable yield (tonnes/ha)	G	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	P	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

*, **Significant at 5 and 1 % respectively

The correlation studies revealed that the gross yield was positively and significantly correlated with plant height, bulb diameter, bulb size index, cloves/bulb, weight of 20 bulbs, bolter, total soluble solids, dry matters and days for harvesting and negatively and significant correlated with clove diameter at genotypic and phenotypic levels (Table 3), indicating that selection based on these traits will help in increasing the yield. Singh *et al.* (1988) and Godhani and Singh (2000) have also reported similar significant positive correlation with bulb yield with bulb weight and size of bulb.

Bulb diameter was significantly and positively correlated with plant height at genotypic level. Weight of 20 bulbs had positive correlation with plant height, bulb diameter and bulb size index. Clove size index was positively and significantly correlated with clove diameter. Cloves per bulb were negatively and significantly correlated with clove diameter and clove size index. It is suggested that, if number of cloves per bulb increased then clove diameter will be reduced. The trait, weight of 50 cloves was significantly and positively correlated with clove diameter and clove size index and negatively correlated with cloves/bulb at both genotypic and phenotypic levels. Dry matter was positively and significant correlated with total soluble solids at both the levels.

Days for bulb initiation had negative and significant correlation with bulb diameter, weight of 20 bulbs and bolters at both genotypic and phenotypic levels. Days for harvesting was negatively and significantly correlated with clove diameter, clove size index and weight of 50 cloves and positively correlated with cloves/bulb and total soluble solids at both levels. It may be concluded from the correlations that the traits, viz plant height, bulb diameter, bulb size index, weigh of 20 bulbs, clove diameter, clove size index, cloves/bulb and days for bulb initiation are correlated to each other and helpful in increasing in total bulb yields.

SUMMARY

A study was conducted at Karnal, Haryana during 2005–07 to identify cloves having high bulb yield with large sized cloves, less number of cloves/bulb and other desirable traits.

From the mean data, it is suggested that, the garlic advance lines ‘G 189’ and ‘G 324’ can be used in breeding programme for yield improvements. High values of heritability, GCV and genetic advance as per cent of mean were observed for bolters, weight of 50 cloves, marketable yield, cloves per bulb, clove size index, clove diameter and weight of 20 bulbs, suggesting that these all traits are genetically controlled by additive gene action. The bulb yield was positively and significantly correlated with neck thickness, bulb diameter, bulb size index, cloves/bulb, bolter, total soluble solids, dry matters, days for harvesting and gross yield at genotypic and phenotypic levels, indicating that selection made on the basis of these traits will be helpful in increasing the yield.

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