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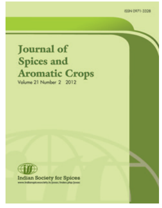

Studies on variability and genetic divergence in elite lines of garlic (*Allium sativum* L.)

R K Singh, B K Dubey & R P Gupta

National Horticultural Research and Development Foundation, Chitegaon Phata
Post-Darna Sangavi, Niphad, Dist-Nashik-422 003, Maharashtra.
E-mail: singhrknbpgr@yahoo.com

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Abstract

The study was conducted during 2006–07 to 2007–08 at Karnal (Haryana), to identify suitable genotypes of garlic for cultivation. The results revealed that a wide range of variability was recorded for gross yield, marketable yield, weight of 50 cloves, number of cloves per bulb, plant height and clove size index. Genotypic and phenotypic coefficients of variations were high for weight of 50 cloves, number of cloves per bulbs, marketable yield and clove size index. Heritability in broad sense ranged from 43.9 to 95.0%. High value of heritability was recorded for plant height followed by cloves per bulb, leaves per plant, weight of 50 cloves, weight of 20 bulbs, marketable yield, bulb size index, and neck thickness. A high estimate of genetic advance was showed by cloves per bulb followed by weight of 50 cloves, marketable yield and weight of 20 bulbs. High values of heritability, GCV and genetic advance as percent of mean were observed for cloves per bulb, weight of 50 cloves, marketable yield, and weight of 20 bulbs. The analysis of variance revealed significant divergence among the thirty two garlic advance lines for different traits, indicating sufficient genetic diversity among the cultivars. The cluster-VII had highest value of plant height (109.11 cm), gross yield (239.19 q ha^{-1}) and minimum stemphylium intensity (2.08%). Cluster VI was promising for leaves per plant (9.51), bulb size index (15.88 cm^2), weight of 20 bulbs (0.696 g) and marketable yield (159.05 q/ha). Cluster X was observed to be promising for bulb diameter (4.63 cm), clove diameter (1.33 cm), clove size index (3.58 cm^2) and weight of 50 cloves (85.0 g). Therefore, it is suggested that selection of genotypes based upon the large cluster distances from all the clusters may lead to broad spectrum favorable genetic variability for bulb yield improvement.

Keywords: *Allium sativum*, D^2 analysis, garlic, genetic divergence, variability

Introduction

Among the spices grown in India, garlic (*Allium sativum* L.) is one of the important spice crops highly placed for its flavor enhancing capacity (Roy & Chakraborti 2002) and high medicinal properties like antimicrobial, antidiabetic and anticarcinogenic action. Garlic has higher nutritive value than other bulb crops and has good export potential as fresh bulb as well as in the form of dehydrated product (Gupta & Singh 1998). Area under garlic during the year 2010–11 was 1.97 lakh ha and production 11.31 lakh tones with average productivity of 5.75 t ha^{-1}. Among different states in India, Madhya Pradesh is the leading state accounting for more than 27% of area and 21% of production with average yield of 4.47 t ha^{-1}. To meet out the domestic requirement and fulfill the export demand, selection of suitable variety for growing under different agro-climatic condition is necessary. Due to asexual propagation, clonal selection is an important breeding method and little work has been done on the association between different traits which are prerequisites for executing a selection programme. Yield being a complex quantitative trait depends on the number of attributes, the knowledge of genetic diversity, its nature and degree of variability would be helpful for selecting desirable genotypes for a successful breeding programme. It will also help for maintaining large number of germplasm by avoiding the duplicates. NHRDF has collected a good number of germplasm from different garlic growing areas. Keeping the above facts in view, the experiment was conducted to determine divergence among existing genotypes and factors influencing genetic diversity and variability of economic traits with the aim to identify suitable genotypes of garlic for cultivation.

Materials and methods

The experiment was carried out at National Horticultural Research and Development Foundation, Salaru, Karnal during 2006–07 and 2007–08. Thirty two diverse genotypes along with five checks *viz.*, Yamuna Safed (G-1), Agrifound White (G-41), Yamuna Safed-2 (G-50), Yamuna Safed-3 (G-282) and Yamuna Safed-4 (G-323) (Table 1) were selected from more than three hundred germplasms from different regions. The experiment was laid out in randomized block design with three replications. Cloves of uniform size (8–10 mm) were selected and planted in first fortnight of October in bed size of 3.0 × 1.5 m with the spacing of 15 × 7.5 cm. The climate of Karnal is subtropical with minimum and maximum temperature ranging between 2^{o}C to 42^{o}C and favorable for garlic cultivation. Recommended

Table 1. List of genotypes and their source of collection

SN	Advance lines	Source of collection	SN	Advance lines	Source of collection
1	G-002	Azadpur, New Delhi	18	G-324	NBPGR, New Delhi
2	G-004	Calcutta, West Bengal	19	G-342	Karnal, Haryana
3	G-023	Rajkot, Gujarat	20	G-351	Singapore
4	G-035	Gondal, Gujarat	21	G-360	Mumbai, Maharashtra
5	G-072	Hissar, Haryana	22	G-366	Indore, Madhya Pradesh
6	G-176	Rajkot, Gujarat	23	G-368	Dindigul, Tamil Nadu
7	G-182	NBPGR, New Delhi	24	G-369	Kota, Rajasthan
8	G-189	NBPGR, New Delhi	25	G-376	Dehradun, Uttaranchal
9	G-192	NBPGR, New Delhi	26	G-378	Dharamshala, Himachal Pradesh
10	G-200	NBPGR, New Delhi	27	G-384	Jaunpur, Uttar Pradesh
11	G-222	NBPGR, New Delhi	28	G-1	Azadpur market, New Delhi
12	G-255	NBPGR, New Delhi	29	G-41	Biharsharif, Bihar
13	G-264	NBPGR, New Delhi	30	G-50	Karnal, Haryana
14	G-294	Maundsaur, Madhya Pradesh	31	G-282	Tamilnadu
15	G-302	Rajkot, Gujarat	32	G-323	Jaunpur, Uttar Pradesh
16	G-304	IARI, New Delhi			
17	G-305	Karnal, Haryana			

*Control; G-1=Yamuna safed; G-41=Agrifound white, G-50=Yamuna safed-2, G-282=Yamuna safed-3; G-323=Yamuna safed-4 cultural operations were carried out to ensure a healthy crop. Harvesting was done as per the maturity of different advance lines. The observations were recorded at maximum growth stage and after harvesting on randomly selected plants in each replications for all the characters *viz.,* plant height (cm), number of leaves^{-1}, 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^{-1}, weight of 50 cloves (g), gross yield (q ha^{-1}), stemphylium blight intensity, nymphs plant^{-1} and marketable yield (q ha^{-1}). The pooled data of both years were analyzed statistically. Variance was analyzed using the standard procedure given by Gomez & Gomez (1984). The genotypic and phenotypic coefficient of variations were analyzed as suggested by Burton & De vane (1958). Heritability in broad sense and expected genetic advance as percent of mean was worked out with method suggested by Johnson *et al.* (1955). Mahalanobis (1936) "D^{2}" statistics was used to find out generalized distance between the genotypes. The D^2 values were used to form cluster following Tocher's method as per Rao (1952). The clusters were grouped into four divergent classes (DC) on the basis of mean (M) and standard deviation (S).

Results and discussion

All the characters showed significant variances, indicating sufficient diversity among the germplasm. A wide range of variability was recorded for gross yield (106.91–263.58 q ha^{-1}), marketable yield (62.40–183.58 q ha^{-1}), weight of 50 cloves (41.66–86.66 g), number of cloves^{-1} (14.0–43.93), weight of 20 bulbs (432.0–767.0 g), and clove diameter (0.91–1.40 cm). Such wide variations among different advance lines could be utilized by plant breeders for the improvement of desired traits. The mean data (Table 2) indicated that the maximum gross yield (263.58 q ha^{-1}) was recorded for advance line G-384 followed by advance line G-324 (260.49 q ha^{-1}), line-G189 (248.15 q ha^{-1}) and G-72 (246.29 q ha^{-1}). Marketable yield (183.58 q ha^{-1}) was also noted for advance line G-384 followed by G-41 (177.28 q ha^{-1}) and G-189 (164.20 q ha^{-1}). The maximum 20 bulbs weight (0.767 kg) and weight of 50 cloves (86.66 g) was observed for check G-282 and G-302 respectively. The highest bulb diameter (4.84 cm) was noted for G-384 and G-305. The lowest stemphylium blight intensity (1.73%), nymphs plant^{-1} (1.86) were recorded for advance lines G-189 and G378 respectively. The mean data indicated that the advance lines G-384, G-189, G-305 and G-282 can be used in garlic crop improvement programme.

The extent of variability with respect to all quantitative characters in different advance lines measured in terms of range, variance, genotypic coefficient of variations (GCV), phenotypic coefficient of variations (PCV), along with heritability (h^2), genetic advance and genetic advances as percent of mean are presented in Table 3. All the characters showed considerable amount of variation. Phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the traits indicating that environmental factor was influencing their expression. Genotypic and phenotypic coefficients of variations were high for nymphs/plant (53.77–60.35%), stemphylium blight (50.50–54.12%), cloves bulb^{-1} (27.53–28.87%), weight of 50 cloves (18.81–19.88%), marketable yield (17.78–20.15%), gross yield (22.70–24.30%) and clove size index (12.62–14.89%). Remaining traits had low genotypic and phenotypic coefficient of variations. Similar results in some important traits were reported by Godhani & Singh (2000) and Shri Dhar (2002). Wide difference between phenotypic and genotypic coefficient of variations indicated their sensitiveness to environmental fluctuations whereas 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.

Heritability in broad sense ranged from 43.9–95.0%. High value of heritability was recorded for plant height (95.0%) followed by cloves bulb^{-1} (90.9%), leaves plant^{-1} (90.3%), weight of 50 cloves (89.6%), gross yield (87.8%), stemphylium blight (87.0%), weight of 20 bulbs

Table 2. Mean performance of different advance line for different traits

Advance lines	Plant height (cm)	Leaves plant^{-1}	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^{-1}	Weight of 50 cloves (g)	Stemphylium blight (Int.)	Nymphs/ plant	Gross yield (q ha^{-1})	Marketable yield (q ha^{-1})
G-002	90.00	8.90	1.66	4.60	15.16	0.633	0.98	2.55	38.93	50.00	2.43	2.06	223.96	143.45
G-004	90.65	8.13	1.44	4.50	14.65	0.710	1.25	3.31	40.46	61.66	8.56	7.96	149.26	147.53
G-023	90.60	8.73	1.66	4.46	14.61	0.622	1.08	2.71	32.66	55.00	3.03	1.93	240.00	137.90
G-035	89.80	8.66	1.56	4.57	14.84	0.560	1.16	3.05	27.53	65.00	4.90	4.00	211.72	131.48
G-072	99.10	8.73	1.64	4.55	14.50	0.605	1.10	2.71	40.06	53.33	3.03	4.73	246.29	140.12
G-176	88.90	9.20	1.41	4.73	15.44	0.703	1.24	3.24	24.23	64.66	7.83	10.73	156.78	154.44
G-182	92.80	8.73	1.63	4.40	14.02	0.600	1.08	2.87	36.66	51.66	3.10	2.40	197.53	123.58
G-189	90.90	8.93	1.62	4.61	15.45	0.685	1.07	2.97	41.80	58.33	1.73	3.20	248.15	164.20
G-192	89.20	8.76	1.46	4.73	16.16	0.717	1.02	2.63	36.50	51.66	10.66	8.06	150.12	148.27
G-200	92.58	8.13	1.45	4.27	13.38	0.663	1.30	3.46	21.23	66.66	10.84	9.6	133.70	129.01
G-222	90.95	8.06	1.42	4.53	14.49	0.667	1.18	3.24	28.23	60.66	8.96	9.63	141.23	138.76
G-255	91.24	8.36	1.51	4.44	14.02	0.693	1.14	2.70	40.46	53.33	6.03	10.70	149.50	145.55
G-264	92.68	9.86	1.46	4.47	14.60	0.707	1.10	2.63	35.50	53.33	9.76	11.73	164.69	162.71
G-294	88.63	8.20	1.56	4.41	14.24	0.540	1.05	2.75	21.00	71.66	4.63	3.80	201.85	120.12
G-302	91.96	8.60	1.53	4.75	16.49	0.727	1.37	3.57	24.00	86.66	11.56	8.96	143.08	138.51
G-304	91.68	8.33	1.48	4.54	15.22	0.717	1.25	2.95	38.70	55.00	5.13	10.2	152.47	149.13
G-305	90.42	8.93	1.50	4.84	16.55	0.730	1.24	3.09	29.16	60.00	5.80	9.83	150.49	148.76
G-324	93.53	8.86	1.52	4.55	15.42	0.685	1.12	2.90	34.06	53.33	2.23	3.53	260.49	154.19
G-342	92.76	8.73	1.68	4.48	13.90	0.615	1.10	2.70	18.80	80.00	4.53	3.13	210.12	102.65
G-351	88.83	8.73	1.56	4.35	14.59	0.607	1.16	2.93	14.26	85.00	9.06	2.26	170.61	105.80
G-360	87.83	8.73	1.53	4.33	13.56	0.432	1.16	2.99	17.20	76.66	5.66	3.46	194.44	62.40
G-366	93.43	7.73	1.41	4.37	15.89	0.720	1.31	3.57	25.93	76.66	5.86	7.96	141.11	136.29
G-368	94.70	9.00	1.66	4.52	14.55	0.592	1.08	2.55	33.93	55.00	1.93	2.4	217.90	128.14
G-369	91.85	8.86	1.48	4.25	13.09	0.627	1.24	3.27	20.10	65.66	6.00	11.43	106.91	98.27
G-376	89.80	8.86	1.58	4.58	15.14	0.633	1.06	2.76	26.53	83.33	2.46	7.53	240.74	145.49
G-378	90.00	8.80	1.59	4.68	14.98	0.542	1.13	2.89	20.66	81.66	4.73	1.86	211.72	104.93
G-384	98.76	9.13	1.66	4.84	17.18	0.732	1.32	2.98	25.06	70.00	2.10	3.4	263.58	183.58
G-1	90.30	9.03	1.39	4.63	15.87	0.657	0.97	2.63	39.73	54.33	7.90	10.30	139.75	137.15
G-41	95.06	9.63	1.51	4.74	17.17	0.723	1.21	3.25	35.16	76.66	13.73	11.66	179.63	177.28
G-50	94.93	8.80	1.60	4.48	14.56	0.627	0.913	2.03	42.93	41.66	6.70	2.86	221.60	126.97
G-282	87.93	8.60	1.55	4.73	16.96	0.767	1.40	3.58	20.26	85.00	8.33	15.39	166.05	151.66
G-323	90.22	9.06	1.51	4.70	15.39	0.710	1.21	3.30	26.60	68.33	6.53	10.06	145.68	140.86
Range	87.83-94.93	7.73-9.86	1.39-1.68	4.25-4.85	13.09-16.96	0.432-0.767	0.91-1.40	2.03-3.58	14.26-43.93	41.66-86.66	1.73-13.73	1.86-11.73	106.91-263.58	62.40-183.58
CD (P<0.005)	2.17	0.250	0.070	0.240	0.900	0.040	0.100	0.380	4.25	6.78	1.940	2.870	25.80	20.90

Table 3. Range, mean, coefficient of variation, heritability and genetic advance for different traits in garlic

Character	Range	CV	SEm (±)	G. Mean	Variance óg	Variance óp	Coefficients of variation PCV (%)	Coefficients of variation GCV (%)	Heritability (%)	Genetic advance	GA as percent of mean
Plant height	21.70	1.41	1.08	94.16	33.71	35.47	6.32	6.16	95.00	11.66	12.38
Leaves plant^{-1}	2.26	1.74	0.124	8.71	0.21	0.240	5.61	5.34	90.30	0.911	10.45
Neck thickness	0.293	2.88	0.036	1.54	0.007	0.009	5.99	5.25	76.80	0.146	9.49
Bulb diameter	0.587	3.24	0.121	4.55	0.017	0.039	4.34	2.87	43.90	0.179	3.92
Bulb size index	4.45	3.65	0.448	15.03	1.042	1.34	7.70	6.78	77.60	1.85	12.31
Weight of 20 bulbs	0.300	4.10	0.022	0.64	0.005	0.005	11.35	10.58	86.90	0.132	20.33
Clove diameter	0.457	5.29	0.050	1.15	0.010	0.014	10.32	8.86	73.70	0.180	15.67
Clove size index	1.833	7.90	0.192	2.97	0.141	0.196	14.89	12.62	71.80	0.656	22.04
Cloves bulbs^{-1}	28.66	8.68	2.12	29.95	68.00	74.77	28.87	27.53	90.90	16.20	54.08
Weight of 50 cloves	45.00	6.41	3.39	64.75	148.48	165.72	19.88	18.81	89.60	23.76	36.69
Stemphylium blight intensity	12.00	19.47	0.973	6.12	9.55	10.97	54.12	50.50	87.10	5.94	97.07
Nymphs plant^{-1}	9.86	27.40	1.43	6.41	11.83	14.96	60.35	53.77	79.40	6.32	98.70
Gross yield (q ha^{-1})	156.66	8.48	12.90	186.25	1800.00	2049.88	24.30	22.78	87.80	81.89	43.97
Marketable yield (q ha^{-1})	121.17	9.48	10.45	134.94	575.87	739.80	20.15	17.78	77.80	43.61	32.32

PCV=Phenotypic coefficient of variation; GCV=Genotypic coefficient of variation; og=Genotypic variance; op=Phenotypic variance

(86.9%), marketable yield (77.8%), bulb size index (77.6%), and neck thickness (77.6%). All the other characters showed moderate heritability. High heritability for the above characters clarified that they were least affected by environmental fluctuations and selection based on phenotypic performance would be reliable. The findings are in consonance with the observations of Korla *et al.* (1981), Jabeen *et al*. (2010) and Tsega *et al*. (2010).

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 percent of mean ranged from 3.92 to 54.08. High estimates of genetic advance was showed by nymphs per plant (98.70%) followed by stemphylium blight intensity (97.07%), cloves bulbs^{-1} (54.08%) followed by weight of 50 cloves (36.69%), marketable yield (32.32%) and weight of 20 bulbs (20.33%) and rest of the traits showed moderate to low genetic advance. High values of heritability, GCV and genetic advance as percent of mean were observed for cloves bulbs^{-1}, weight of 50 cloves, marketable yield, 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 and family selection. High heritability coupled with low genetic advance as percent of mean with low GCV were observed for all the traits which suggested that these traits were governed by non additive gene action and have high genotype × environment interaction. High genetic advance recorded for number of cloves bulb^{-1}, gross yield and weight of bulbs are in agreement with the finding of Padda *et al.* (1972).

The analysis of variance revealed significant divergence among the thirty two lines for all the traits indicating sufficient genetic diversity among the cultivars. On the basis of D^2 values, all the thirty two genotypes were grouped in ten clusters (Table 4). The cluster II was the largest consisting of nine genotypes followed by cluster I, III, VI having seven, four and three genotypes respectively. Cluster IV, VII, VIII

Table 4. Distribution of thirty two garlic advance lines in different clusters obtained by multivariate analysis

Cluster	Number of garlic advance lines	Name of garlic advance lines
I	7	G-002, G-023, G-072, G-189, G-182, G-50 and G-384
II	09	G-004, G-304, G-255, G-222, G-366, G-192, G-323, G-302 and G-305
III	04	G-035, G-294, G-360 and G-376
IV	02	G-176 and G-369
V	01	G-200
VI	03	G-264, G-1 and G-41
VII	02	G-324 and G-386
VII	02	G-342 and G-378
IX	01	G-351
X	01	G-282

consisted of two genotypes each. The smallest cluster having one genotype each was V, IX and X. The genotypes belonging to same status or origin were grouped into different clusters and the genotypes belonging to different origin were grouped in same clusters. The grouping pattern of the genotypes suggested no parallelisms between genetic divergence and geographical distribution of genotypes. Singh & Dubey (2011), Lokhande *et al.* (1987), Lee *et al.* (1996), Mohanty (2001) and Mohanty & Prusti (2002) also reported that genotype diversity was independent of geographical region.

Intra and inter cluster D^2 values and corresponding genetic distance are presented in Table 5. The cluster II had maximum intra-cluster genetic distance (98.19) followed by

Table 5. Intra and inter cluster D^2 value (Light) and distance ("D^2) (dark) in garlic advance lines

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X
I	71.98 **(8.48)**	205.18 **(14.32)**	259.62 **(16.11)**	278.43 **(16.69)**	302.22 **(17.38)**	294.84 **(17.17)**	191.48 **(13.84)**	228.9 9**(15.13)**	460.03 **(21.45)**	367.01 **(19.16)**
II		98.19 **(9.91)**	299.20 **(17.30)**	128.04 **(11.32)**	135.46 **(11.64)**	190.15 **(13.79)**	427.02 **(20.66)**	379.72 **(19.49)**	449.11 **(21.19)**	359.97 **(18.97)**
III			**96.46** **(9.82)**	255.89 **(16.00)**	392.62 **(19.81)**	444.46 **(21.08)**	592.28 **(24.34)**	226.48 **(15.05)**	152.19 **(12.34)**	162.33 **(12.74)**
IV				75.55 **(8.69)**	113.62 **(10.66)**	176.40 **(13.28)**	506.66 **(22.51)**	361.43 **(19.01)**	355.17 **(18.85)**	395.02 **(19.89)**
V					0.00 **(0.00)**	274.88 **(16.58)**	440.30 **(20.98)**	404.42 **(20.11)**	504.78 **(22.47)**	415.41 **(20.38)**
VI						97.78 **(9.89)**	492.18 **(22.19)**	547.08 **(23.39)**	611.21 **(24.72)**	680.08 **(26.08)**
VII							60.02 **(7.75)**	278.95 **(16.70)**	801.69 **(28.31)**	668.74 **(25.86)**
VII								59.90 **(7.74)**	240.16 **(15.50)**	206.01 **(14.35)**
IX									0.00 **(0.00)**	160.60 **(12.67)**
X										0.00 **(0.00)**

cluster VI (97.78) due to single genotypes. Clusters with single genotype (V, IX and X) obviously had zero intra cluster value indicating their independent identity and importance due to various unique characters possessed by them. The intra cluster values are lesser than inter cluster values. The inter cluster distance (D^2) is the main criterion for selection of genotype. The maximum inter cluster D^2 values (801.69) was noted between clusters VIII and X, indicating a wider genetic diversity between the genotypes in these groups. Inter cluster distance was minimum (113.62) between clusters IV and VI indicating close relationship and similarity for most of the traits of the genotypes in these clusters. Arunachalam (1981) also stated that genotypes belonging to the cluster with maximum inter cluster distance are genetically more divergent. Therefore, it is suggested that selection of genotypes based upon large cluster distances from all the clusters may lead to favorable broad spectrum genetic variability for bulb yield improvement. Estimates of the cluster means for different traits are measures of inter cluster divergence and degree of homogeneity. Hence, cluster means were worked out (Table 6), which indicated that different clusters were superior with respect to various traits.

The cluster VII had highest value of plant height (109.11 cm), gross yield (239.19 q ha^{-1}) and minimum stemphylium intensity (2.08%). Cluster I was promising for cloves $bulbs^{-1}$ (36.87). The minimum neck thickness (1.45 cm) was showed by cluster V. Cluster VI was promising for leaves $plant^{-1}$ (9.51), bulb size index (15.88 cm^2), weight of 20 bulbs (0.696 g) and marketable yield (159.05 q ha^{-1}). Highest weight of 50 cloves (85.0 g), minimum cloves $bulbs^{-1}$ (14.26) and nymphs $plant^{-1}$ (2.26) was recorded in cluster IX. Cluster X was promising for bulb diameter (4.63 cm), clove diameter (1.33 cm), clove size index (3.58 cm^2) and weight of 50 cloves (85.0 g). The clusters VI, VII, and X had more and less average values for most of the traits like yield and yield contributory traits.

The individual characters contributing maximum to the D^2 values are to be given greater emphasis for deciding the cluster for the

Table 6. Cluster mean for different traits in garlic advance lines

Characters	Clusters										% Contributions
	I	II	III	IV	V	VI	VII	VIII	IX	X	
Plant height	98.15	91.08	89.01	90.38	92.58	92.68	109.11	101.88	88.83	87.93	22.98
Leaves $plant^{-1}$	8.85	8.44	8.61	9.03	8.13	9.51	8.93	8.76	8.73	7.60	11.69
Neck thickness	1.64	1.47	1.56	1.45	1.45	1.45	1.59	1.64	1.56	1.55	1.00
Bulb diameter	4.56	4.61	4.47	4.49	4.27	4.61	4.53	4.58	4.35	4.63	5.84
B. Size index	15.07	15.54	14.44	14.26	13.38	15.88	14.98	14.44	14.59	14.96	1.63
Wt. of 20 bulbs	0.643	0.711	0.541	0.665	0.663	0.696	0.638	0.579	0.607	0.587	6.04
Clove diameter	1.054	1.22	1.11	1.24	1.30	1.09	1.10	1.12	1.16	1.33	1.00
Cl. size index	2.63	3.17	2.89	3.25	3.46	3.00	2.73	2.79	2.93	3.58	0.202
Cloves $bulb^{-1}$	36.87	32.23	23.06	22.16	21.23	36.80	34.00	19.73	14.26	20.26	15.12
Wt. of 50 cloves	54.28	63.77	74.16	65.16	66.66	61.44	54.16	80.83	85.00	85.00	3.22
S. blight intensity	3.61	7.68	4.41	6.91	10.84	10.46	2.08	4.63	9.06	8.33	20.16
Nymphs $plant^{-1}$	2.94	9.26	4.70	11.08	9.60	11.23	2.96	2.50	2.26	3.66	0.605
Gross yield	235.73	146.99	212.19	131.85	133.70	161.35	239.19	210.92	170.61	186.05	10.28
Marketable Yield	145.68	143.74	114.89	126.35	129.01	159.05	141.17	103.79	105.80	90.49	0.202

purpose of further selection. The study revealed that plant height contributed maximum (22.98%) towards genetic divergence followed by stemphylium blight intensity (20.16%), cloves bulb^{-1} (15.12%), leaves plant^{-1} (11.69%), gross yield (10.28%), weight of 20 bulbs (6.04%) and bulb diameter (5.84%). All these traits are considered to be most important for genetic divergence and they contributed 92.11% towards genetic divergence in this investigation. Similar findings for contributions regarding marketable yield and gross yield were reported by Khar *et al.* (2006) and Mehta *et al.* (2005). The analysis of genetic diversity in garlic genotypes will help us in avoiding duplicates and minimize the efforts for maintenance of germplasm. This also indicated that there is good scope for selection of varieties for desirable traits and cultivation in different part of the country for higher productivity.

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References

Arunachalam V 1981 Genetic distance in plant breeding. Ind. J. Gen. 41: 226–36.

Burton G W & De Vane E H 1958 Estimating heritability in tall Fescue (*Festuce arundinacua*) from replicated clonal materials. Agron. J. 45: 475–81.

Gomez A K & Gomez A A 1984 Statistical procedures for agricultural research. John Willey and Sons Inc., New York, 657p.

Godhani P V & Singh S P 2000 Genetic variability, correlation and path coefficient studies in Garlic (*Allium sativum* L). In: Kirti Singh, Lawande K E, Pandey U B, Lallan Singh & Bhonde S R. (Eds.). Approaches for sustainable development of onion and garlic (pp. 95–98). Proceedings of the National Symposium on onion and garlic production and post harvest management challenges and strategies, 19–21 November 2000, Nashik.

Gupta R P & Singh D K 1998 Studies on the performance of different advance lines in garlic, National Horticultural Research and Development Foundation (NHRDF), News letter, Vol. XVIII(3): 13.

Jabeen N Khan, S H Chattoo M A Mufti, S & Hussain K 2010 Genetic variability for various traits in garlic (*Allium sativum* L.). Ind. J. Areca. Spices Medic. Plant 12: 13–17.

Johnson H W, Robinson H F & Comstock R E 1955 Estimates of genetic and environmental variability in soybean. Agron. J. 47: 314–318.

Khar A, Asha Devi A, Mahajan V & Lawande K E 2006 Genetic divergence analysis in elite lines of garlic (*Allium sativum* L). J. Maharashtra Agric. Univ. 31: 52–55.

Korla B N, Singh A K & Kalia P 1981 Genetic variability in garlic. Haryana J. Hort. Sci. 10: 77–80.

Lee E T, Ching D H, Kwon B S, Jeong B C, Hwang J J & Lim J T 1996 Varietal classification by multivariate analysis in onion (*Allium cepa* L.). J. Korean Soc. Hort. Sci. 37: 37–41.

Lokhande G D, Pawar B B, Dumbre A D & Thete R Y 1987 Genetic divergence in garlic (*Allium sativum* L.). Cur. Res. Rep. 3: 98–99.

Mahalnobis P C 1936 On the generalized distance in statistics. Proc. Nat. Inst. Sci. 12: 49–55.

Mehta D R, Dhaduk L K & Kalathia K V 2005 Genetic variability, diversity, correlations and path coefficient analysis of Indian cultivars of onion under Saurashtra region of Gujrat. Recent Advances in Allium Research, Proceeding of First National Conference on Alliums, Department of Mycology and Plant Pathology (pp. 128–142), Institute of Agricultural Science, Banaras Hindu University, Varanasi, 24–25 February 2005.

Mohanty B K 2001 Analysis of genetic divergence in *Kharif* onion. Ind. J. Hort. 58: 260–63.

Mohanty B K & Prusti A M 2002 Mahalanobis's generalized distance analysis in onion. Res. Crops. 3: 142–144.

Padda D S, Singh G & Saimbhi M S 1972 Genetic variability and correlation studies in onion. Ind. J. Hort. 30: 391–393.

Panse V G 1957 Genetics of quantitative characters in relation to plant breeding. Ind. J. Genet. 17: 311–29.

Rao C R 1952 Advanced Statistical Methods in Biometrical Research, John Willey and Sons, New York. pp. 357–64.

Roy S K & Chakraborti A K 2002 Post harvest management and processing of onion and garlic. In: Singh H P, Mann J S, Pandey U B, Lallan Singh & Bhonde S R (Eds.) Souvenir Onion and Garlic: Production-Utilization (pp. 66–72). A consultative meeting on accelerated production and export of onion and garlic, held at New Delhi 19–20 April 2002.

Shri Dhar 2002 Genetic variability and characters association in garlic. Prog. Hort. 34: 88–91.

Singh R K & Dubey B K 2011 Studies on genetic divergence in onion advance lines. Ind. J. Hort. 68: 123–127.

Tesga K, Tiwari A & Woldetsadik K 2010 Genetic variability, correlation and path coefficient among bulb yield and yield traits in Ethiopian garlic germplasm. Ind. J. Hort. 67: 489–499.