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GENETIC PARAMETERS AND DIVERSITY STUDIES AMONG MORPHOLOGICAL TRAITS IN BREEDING LINES OF GARLIC (*ALLIUM SATIVUM* L.)

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Abstract

Thirty-four promising lines of garlic were grown in randomized block design with three replications under the latesown season in 2019-20 at Vegetable Research Farm of C. S. Azad University of Agriculture and Technology, Kalyanpur, Kanpur. The mean sum of squares showed highly significant differences among the lines for all the traits studied, indicating the presence of a sufficient amount of genetic variability. The moderate to higher magnitude of the coefficient of variation at genotypic as well as phenotypic levels was noticed for number of cloves per bulb, marketable bulb yield, average weight of bulb, average weight of cloves and plant height. High heritability coupled with high genetic advance as percent of mean was observed for plant height, leaf length, leaf width, polar diameter, number of cloves per bulb, average weight of bulb and average weight of cloves. Marketable bulb yield was positively and significantly correlated with the total bulb yield and dry matter content whereas, a significant negative correlation with leaf width. All the thirty-four lines of garlic were grouped into five clusters based on Mahalanobis D^2 statistics using Tocher's method. The cluster II and V had among the moderate genetic distance having higher total bulb yield performance along with its contributing traits. The genotypes from cluster IV and V had the most divergent clusters and were suitable for high yielding garlic genotypes among the various advanced breeding lines under late sown conditions.

Introduction

Garlic (*Allium sativum* L.) is an important spice and condiment crop of India. It belongs to Amaryllidaceae and is an important bulbous vegetable crop grown commercially and used as a valuable spice throughout India. Garlic is propagated exclusively by cloves on a vegetative basis and its scope of development over breeding methods is inadequate.

India is the second largest producer of garlic after China with an annual production of 2910 thousand metric tonnes and productivity of 8.12 tonnes per hectare (FAOSTAT 2019).The genetic makeup of plants determines their yield potential. The vegetative growth of garlic starts mostly during the cool season but when it is sown during late season it faces high temperature and attack of more incidence of pest and diseases which do not give better crop performance and desirable results.

Garlic is cultivated in many parts of India and has a wide range of variability among the different quantitative and quality characters. Information on the nature and extent of genetic variability and the degree of transmission of traits is of paramount importance in enhancing the efficiency of selection. However, knowledge of correlation among various characters and their relative contribution to yield is useful for multiple trait selection. Knowledge on the association of these traits with yield will be more useful to plan the selection strategies for improving the bulb yield. The D^2 statistics is a powerful tool for quantifying the genetic divergence. It gives a better idea about the magnitude of the divergence which is independent of the size of the sample and

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provides the basis for the selection of parental lines for the future breeding prgramme. Thus, the present study was carried out to assess the genetic diversity, variability and an association of different traits with the aim to identify suitable genotypes of garlic under late planting.

Material and Methods

In the present study 34 lines of garlic were grown in randomized block design with three replications under late sown environment (25 November 2019) at Vegetable Research Farm of C. S. Azad University of Agriculture and Technology, Kalyanpur, Kanpur. Each genotype/line was sown in 20 rows of 3 m long spaced at 15 cm apart. There were 20 plants per row and were spaced at 10 cm apart. In this way, there were 400 plants per plot.All the recommended packages of practice were adopted for raising healthy crops. Observations were recorded from 10 randomly selected plants for plant height (cm), number of leaves per plant, leaf length (cm), leaf width (cm), days to maturity, polar diameter (cm), equatorial diameter (cm), number of cloves per bulb, average weight of bulb (g), average weight of 10 cloves (g), total bulb yield (q/ha), marketable bulb yield (q/ha), total soluble solids (%) and dry matter content (%). Data were statistically analyzed using standard procedures suggested by Panse and Sukhatme (1967). Genotypic coefficient of variation (GCV) and phenotypic coefficient variation (PCV) was estimated using the formula of Burton and Dewane (1952). Heritability in the broad sense (h^2) and expected genetic advance (GA) were worked out according to Johnson *et al.* (1955). A phenotypic and genotypic correlation was worked out as per Al-Jibouri *et al.* (1958). Mahalanobis (1936) D^2 statistics was used for assessing genetic divergence among all the genotypes. The genotypes were grouped into different clusters by following Tocher's method as described by Rao (1952), while the intra and inter cluster distances were calculated using the formula given by Singh and Choudhary (1985).

Results and Discussion

The analyses of variance revealed that the mean square of genotypes was significant for all the characters (Table 1). A wide range of variability was noticed for different qualitative and quality traits. The highest range of variation was recorded for total bulb yield (48.59 to 78.82 q/ha), plant height (36.24 to 64.89 cm), marketable bulb yield (30.48 to 55.28 q/ha), days to maturity (135.00 to 151.33 days) and average weight of fresh bulb (13.20 to 26.49 g) suggesting adequate variability among the genotypes under late planting. The extent of variability concerning all the characters in different promising lines was estimated in terms of range, genotypic and phenotypic coefficient of variation (GCV and PCV), along with heritability (h^2), genetic advance and genetic advances as a percent of the mean (Table 2). In the present study, all traits examined had a higher PCV than the GCV with a narrow difference indicating that the environmental influence was least and there was a preponderance of genetic factors controlling variability in these traits. Among all traits examined, moderate to the high phenotypic and genotypic coefficient of variation (PCV and GCV) was noticed for number of cloves per bulb (15.43 and 14.06), marketable bulb yield (18.50 and 15.49), average weight of bulb (18.61 and 17.80), average weight of cloves (20.91 and 19.89) and plant height (20.40 and 20.08), respectively. In all respect of traits, moderate to high values of PCV and GCV observed for the above traits indicated the influence of genetic control and less affected by environment and these traits can be practiced for further improvement through selection.

In the present investigation, estimates of broad sense heritability (h^2) ranged from 49.61 to 96.90%. The most intriguing finding is of the present high heritability (> 80 %) in a broad sense which was recorded for plant height (96.90%), polar diameter (95.31%), leaf width (94.98%), average weight of bulb (91.39%), average weight of 10 cloves (90.46%), leaf length (86.31%), equatorial diameter (85.65 %) and number of cloves per bulb (83.01%). High heritability helps to identify appropriate character for selection and enables the breeder to select superior genotypes based on phenotypic expression of qualitative traits. The findings agree with the traits of Sharma *et al.* (2016), Meena *et al.* (2020) and Kumari (2021).

Table 1.Analysis of variance for different characters of garlic genotypes.

Characters	Mean sum of squares			SE(d)
	Replications (*df*= 2)	Genotypes (*df*= 33)	Error (*df*= 66)	
Plant height (cm)	7.69	261.52**	2.75	1.35
Number of leaves per plant	0.21	1.22**	0.22	0.38
Leaf length (cm)	6.71	42.03**	2.11	1.18
Leaf width (cm)	0.01	0.11**	0.00	0.03
Days to maturity	16.08	54.93**	8.02	2.31
Polar diameter (cm)	0.01	0.30**	0.00	0.06
Equatorial diameter (cm)	0.01	0.32**	0.01	0.10
Number of cloves per bulb	1.48	24.40**	1.55	1.01
Average weight of bulb (g)	0.13	35.34**	1.07	0.84
Average weight of 10 cloves (g)	0.19	5.33**	0.18	0.34
Marketable bulb yield (q/ha)	18.20	160.45**	19.92	3.64
Total bulb yield (q/ha)	43.69	202.00**	17.73	3.43
Total soluble solids (%)	8.68	17.23**	4.35	1.70
Dry matter content (%)	0.16	29.41**	4.05	1.64

**Significant at 0.01 probability level.

Estimates of genetic advances predict the improvement that can be achieved for improving the different traits. From the present investigation, a high genetic advance was observed for plant height (38.78), total bulb yield (29.29) and marketable bulb yield (24.32). Observation of high heritability coupled with high genetic advance as percent of the mean (> 40 %) for plant height, leaf length, leaf width, polar diameter, number of cloves per bulb, average weight of bulb and average weight of cloves suggest the preponderance of additive genes. It also indicated a higher response for the selection of high yielding genotypes as these characters are governed by additive gene actions. It is supported by similar findings reported by Dhall and Brar (2013), Kumar *et al.* (2015) and Sharma *et al.* (2016).The traits having high values of heritability supplemented with moderate genetic advance as percent of mean were manifested by an equatorial diameter which may be attributed to additive genes but selection for these traits may be less effective. These results are in agreement with the findings of Yadav *et al.* (2012) for pseudostem diameter and polar diameter of bulb.

The present study showed an almost close relation between genotypic and phenotypic correlation coefficient indicating a negligible influence of environment. The further genotypic coefficient was almost higher than the corresponding phenotypic correlation coefficient which indicated strong association at a genotypic level between two characters. In the present study,the association of phenotypic and genotypic levels was worked out for bulb yield and developmental

Table 2. Estimation of genetic parameters for bulb yield and its component characters in garlic.

Characters	Grandmean	Ranges		PCV	GCV	H^2_B	GA	GAM
		Min.	Max.					
Plant height (cm)	46.25	36.24	64.89	20.40	20.08	96.90	38.78	83.84
Number of leaves per plant	6.64	5.33	7.80	11.23	8.71	60.22	1.91	28.76
Leaf length (cm)	32.30	26.40	39.92	12.16	11.29	86.31	14.37	44.48
Leaf width (cm)	1.59	1.31	2.06	12.61	12.27	94.98	0.80	50.31
Days to maturity	141.5	135.00	151.33	9.60	8.93	66.07	13.63	9.62
Polar diameter (cm)	3.25	2.68	4.00	10.49	10.24	95.31	1.38	42.46
Equatorial diameter (cm)	3.45	2.85	4.04	10.07	9.32	85.65	1.25	36.23
Number of cloves per bulb	19.62	14.66	27.30	15.43	14.06	83.01	10.67	54.38
Average weight of bulb (g)	19.04	13.20	26.49	18.61	17.80	91.39	13.76	72.23
Average weight of 10 cloves (g)	6.59	4.86	10.38	20.91	19.89	90.46	5.29	80.27
Marketable bulb yield (q/ha)	44.17	30.48	55.28	18.50	15.49	70.16	24.32	55.05
Total bulb yield (q/ha)	65.13	48.59	78.82	13.66	12.03	77.60	29.29	44.97
Total soluble solids (%)	42.25	38.02	45.97	6.96	4.90	49.61	6.20	14.67
Dry matter content (%)	36.62	29.73	41.93	9.66	7.94	67.57	10.13	27.66

PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, h^2_b= Heritability(in broad sense) GA = Genetic advance, GAM=Genetic advance as percentage of mean.

Table 3. Phenotypic and genotypic correlation among different yield attributing characters in garlic.

Characters		NOL	LL	LW	DTM	P	E	NOC	ABW	AWC	TBY	TSS	DM	MBY
PH	RP	0.307**	0.606**	0.412**	0.196*	0.007	0.078	0.077	0.426**	0.359**	0.014	0.117	-0.037	0.057
	RG	0.395**	0.662**	0.428**	0.243*	0.011	0.078	0.088	0.446**	0.390**	0.026	0.135	-0.068	0.081
NOL	RP		0.249*	0.259**	0.133	-0.031	-0.062	0.079	0.211*	0.026	-0.152	-0.203*	-0.079	-0.146
	RG		0.313**	0.342**	0.106	-0.026	-0.031	0.135	0.302**	0.018	-0.198*	-0.387**	-0.185	-0.165
LL	RP			0.368**	0.316**	0.150	0.197*	0.121	0.583**	0.626**	0.001	-0.016	-0.189	0.024
	RG			0.388**	0.399**	0.160	0.211*	0.180	0.689**	0.713**	-0.001	-0.074	-0.251*	0.050
LW	RP				0.276**	0.369**	0.387**	-0.021	0.432**	0.402**	-0.314**	-0.205*	-0.297**	-0.221*
	RG				0.334**	0.387**	0.434**	-0.019	0.461**	0.439**	-0.366**	-0.303**	-0.363**	-0.261**
DTM	RP					0.257**	0.269**	0.038	0.332**	0.072	-0.066	-0.113	0.004	0.039
	RG					0.317**	0.363**	-0.033	0.385**	0.034	-0.086	-0.243*	0.143	0.035
P	RP						0.856**	-0.133	0.165	0.173	0.169	-0.274**	-0.051	0.170
	RG						0.945**	-0.139	0.188	0.176	0.176	-0.360**	-0.034	0.183
E	RP							-0.067	0.212*	0.180	0.090	-0.115	-0.017	0.064
	RG							-0.065	0.245*	0.188	0.080	-0.198*	-0.035	0.059
NOC	RP								0.387**	0.152	0.082	0.191	0.075	0.008
	RG								0.439**	0.179	0.081	0.188	0.104	-0.011
ABW	RP									0.489**	-0.037	-0.190	-0.013	0.001
	RG									0.531**	-0.039	-0.295**	-0.018	0.012
AWC	RP										0.028	0.031	-0.307**	0.052
	RG										0.015	0.053	-0.349**	0.062
TBY	RP											-0.059	0.340**	0.913**
	RG											-0.085	0.485**	0.962**
TSS	RP												0.072	-0.139
	RG												0.037	-0.186
DM	RP													0.344**
	RG													0.499**
MBY														-
														-

* and ** indicates significance of values at P=0.05 and P=0.01, respectively. PH=Plant height (cm); NOP= Number of leaves/plant; ; LL=Leaf length (cm); LW=Leaf width (cm); DTM= Days to maturity; P=Polar diameter (cm); E=Equatorial diameter (cm) NOC=Number of cloves/bulb; ABW= Average bulb weight (g); AWC= Average weight of 10 cloves; TBY= Total bulb yield (q/ha); MBY=Marketable bulb yield (q/ha); TSS=Total soluble solids(%); DM=Dry matter content (%).

traits along with quality attributes traits. Results showed significant positive correlations at a phenotypic and genotypic levels for marketable bulb yield per hectare with total bulb yield (0.913 and 0.962) and dry matter content (0.344 and 0.499) whereas, significant negative correlation with leaf width (-0.221 and -0.261) (Table 3). Singh and Dubey (2011) reported a strong positive and significant correlation of marketable yield with number of leaves per plant, bulb diameter, bulb size index, weight of bulbs and cloves per bulb. Average weight of bulb showed a significant positive correlation with leaf length (0.583 and 0.689), average weight of cloves (0.489 and 0.531), leaf width (0.432 and 0.461), plant height (0.426 and 0.446), and number of cloves per bulb (0.387 and 0.439). Similar findings were reported by Dhall and Brar (2013), Khar *et al.* (2015), Sharma *et al.* (2016) and Shibana and Menon (2019). Average weight of cloves was positively correlated with leaf length (0.626 and 0.713) followed by average weight of bulb (0.489 and 0.531) leaf width (0.400 and 0.439) and plant height (0.359 and 0.390), while it was negatively and significantly correlated with dry matter content hence indicating genetic improvement of bulb yield in garlic by putting positive selection pressure on various characters like leaf length, average weight of bulb, leaf width and plant height.

In the present study, all the 34 genotypes were grouped into five clusters, depending upon the genetic constitution of the genotypes (Table 4). Cluster II was the largest consisting of eight genotypes. Cluster IV and V contain seven genotypes each; whereas, six genotypes were present in each of clusters I and III. This indicated that there was sufficient diversity among the various genotypes for study the characters.

Table 4. Distribution of garlic genotypes in different clusters.

Cluster No.	No. of genotypes	Name of genotypes
I	6	KLG-6, KLG-18, KLG-19, KLG-21, KLG-22, KLG-23
II	8	G-384, G-282, PKVG-07, KLG-1, KLG-8, KLG-13, KLG-16, KLG-26
III	6	KLG-3, KLG-5, KLG-9, KLG-11, KLG-12, KLG-20
IV	7	G-189, Bhima Purple, PKVG-05, PGS-204, G-50, KLG-2, KLG-4
V	7	KLG-7, KLG-10, KLG-14, KLG-15, KLG-17, KLG-24, KLG-25

Table 5. Intra and inter cluster distance (√ d) between 34 lines of garlic.

Cluster	I	II	III	IV	V
I	2.768	4.122	3.426	5.082	3.545
II		3.624	4.395	4.021	4.280
III			3.069	4.084	3.730
IV				3.450	5.150
V					3.043

The inter cluster distance is the main criterion for the selection of genotype as parents for crop improvement program by using D^2 Mahalanobis analysis. It also helps to know the relative distances between these genotypes for the characters under study. The maximum intra cluster distance was found in cluster II (3.624) followed by cluster IV (3.450) and cluster III (3.069) (Table 5). Inter cluster values varied from 3.426 to 5.150. The maximum inter cluster value was noticed between cluster IV and V (5.150) followed by cluster I and IV (5.082) and cluster II and III (4.395). The minimum inter cluster distance was observed between cluster I and III (3.426) indicating a close relationship and similarity for most of the traits of the genotypes in these clusters. Cluster divergence indicated that these genotypes may be used to produce more number of superior heterotic response and large number of desirable transgressive segregates. This genetic diversity among the genotypes might be due to several factors such as the exchange of breeding material, selection, natural variation under diverse environments and genetic drift.

The composition of cluster means values for the different traits indicated considerable differences between clusters and each trait (Table 6). Cluster IV possessed high mean values for plant height (53.52 cm), leaf width (1.78 cm), days to maturity (146.10 days), polar diameter (3.61 cm), equatorial diameter (3.80 cm) and marketable bulb yield (48.62 q/ha); cluster II for number of leaves per plant (7.05 cm), leaf length (21.97 cm), average weight of bulb (22.10 g) and average weight of cloves (7.53 g); cluster V for total bulb yield (70.60 q/ha), total soluble solids (44.10 %) and dry matter content (39.06 %).Clusters I and III had fewer average values for all traits among the clusters. These results obtained are in accordance with the findings of Singh and Dubey (2011) in onion and Singh *et al.* (2013), Sandhu *et al.* (2014) and Mishra *et al.* (2018) in garlic.

Table 6. Cluster wise mean values of 14 characters in garlic.

Characters	Cluster				
	I	II	III	IV	V
Plant height (cm)	39.99	49.78	38.35	53.52	47.12
Number of leaves per plant	6.83	7.05	6.14	6.74	6.34
Leaf length (cm)	29.84	35.26	29.41	34.94	30.87
Leaf width (cm)	1.48	1.75	1.46	1.78	1.46
Days to maturity	139.00	142.00	142.56	146.10	138.00
Polar diameter (cm)	3.12	3.14	3.50	3.61	2.94
Equatorial diameter (cm)	3.27	3.38	3.70	3.80	3.14
Number of cloves per bulb	17.66	21.97	19.57	17.98	20.33
Average weight of bulb (g)	15.50	22.10	18.41	20.51	17.72
Average weight of 10 cloves (g)	5.77	7.53	5.46	7.16	6.62
Marketable bulb yield (q/ha)	40.92	38.25	45.50	48.62	48.16
Total bulb yield (q/ha)	62.54	57.37	67.07	69.12	70.60
Total soluble solids (%)	41.66	42.24	42.33	40.87	44.10
Dry matter content (%)	33.63	34.62	38.43	37.50	39.06

Table 7. Contribution (%) of different characters towards clustering in garlic.

Character name	Contribution (%)	Character name	Contribution (%)
Plant height (cm)	29.05	Number of cloves per bulb	1.06
Number of leaves per plant	0.53	Average weight of bulb (g)	11.05
Leaf length (cm)	0.53	Average weight of 10 cloves (g)	5.70
Leaf width (cm)	9.62	Marketable bulb yield (q/ha)	0.53
Days to maturity	2.13	Total bulb yield (q/ha)	2.31
Polar diameter (cm)	20.14	Total soluble solids (%)	0.17
Equatorial diameter (cm)	0.00	Dry matter content (%)	1.06

The percentage contribution of plant height (29.05%) has been maximum to divergence followed by polar diameter (20.14), average weight of bulb (11.05), leaf width (9.62) and average weight of cloves (5.70) contributed more than 75 % towards the total divergence (Table 7).Parallel to the present results, maximum contribution towards the divergence for plant height was previously reported by Singh *et al*. (2012) and Mishra *et al*. (2018).

Keeping in view the above aspect, the genotypes of clusters IV and V under late sown condition exhibited maximum cluster divergence which is indicated that these genotypes may be used to produce higher bulb yield under late sown conditions. Furthermore, the lines of these clusters could be used as a parent in a hybridization programme to get the higher heterotic effect or to isolate a good variant as genotypes from the segregating population. Hence, the result of the present study can be used for evolving well-defined approach based on evaluation and characterization of variation in garlic and can be utilized in various breeding programmes.

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