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Correlation and path coefficient studies in garlic (*Allium sativum* L.) over different environments

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Garlic is regarded as one of the important bulb crops grown and used as a spice or condiment throughout India (Singh and Srivasatava, 1999). It is used as food, condiment and medicine by many civilizations in Asia and the Mediterranean region. It also has good export potential as bulb as well as in the form of dehydrated products.

Lack of flowering in most cultivated clones and seed sterility in those that do flower have also restricted the sexual breeding and genetic studies in garlic (Ipek *et al*., 2003). It is assumed that the vast diversity that has been observed in cultivated garlic goes back to variation generated from sexual reproduction in the wild crop (Simon 2001). Existence of this natural variation even in respect of the plant parts that is economically important suggests the possibility of improvement in garlic. Once quantitatively and qualitatively superior clones are identified, their maintenance through vegetative propagation is assured (Yudhvir Singh and Ramesh Chand, 2003). Therefore, genetic variability, character association pattern and direct and indirect effect of the yield contributing characters on bulb yield under different environmental conditions is helpful for effective selection in crop improvement. The present study was undertaken with these objectives and so that appropriate breeding strategies for bulb yield improvement in garlic could be worked out.

The experiment was conducted at Main Vegetable Research Station, Anand Agricultural University, Anand using 14 genotypes and 2 checks GG-3 (Gujarat Garlic-3) and G-282 (NC) during the three seasons viz., *rabi* 2006-07 (E_1), *rabi* 2007-08 (E_2) and *rabi* 2008-09 (E_3). Randomized Block Design with 3 replications was followed in the experiment. Planting was done in the first fortnight of October keeping the distance of 15cm x 10cm. The plot size was of 2.00m x 2.25m. All the recommended techniques and plant protection measures were followed uniformly. Harvesting was arranged as per the maturity of different genotypes. The data were recorded on bulb yield and its contributing attributes (Table 1).

Analysis of variance was done using the method of Steel and Torrie (1084). Genotypic and phenotypic correlations were worked out according to the method given by Kwon and Torrie (1964). The direct and indirect effects of each trait were assessed by path analysis using the method of Dewey and Lu (1959).

In the present study, in almost all the cases genotypic correlations coefficient were higher as compared to phenotypic correlation coefficient in the all the environments. This finding suggests that all the character govern by additive genetic effect and that was not influenced by any environmental effect. It means that selection for yield contributing characters were directly influence the bulb yield and that will be fixable as it will govern by additive gene effect.

The analysis of Variance indicated significant differences among the genotypes for all the character except polar diameter at E_1. These indicated sufficient variability existed in the material studied.

Phenotypic correlations for all possible combinations for traits under study over three environments are presented in Table 1, respectively. The observations regarding the association of various traits are explained as under.

The result indicated that 10 bulb weight and number of cloves per bulb were positively and significantly correlated with bulb yield with in all three environments which suggesting that plant with higher 10 bulb weight and number of cloves per bulb produce higher bulb yield irrespective of environments. The above findings conform to the earlier reports of Kohli and Nutan (1993) and Panthee *et al* (2006). In the same way, plant height was positively significantly correlated with number of

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leaves per plant per plant, 10 bulb weight and number of cloves per bulb at genotypic and phenotypic levels in all the three environments except plant height with 10 bulb weight in E_1 at both genotypic and phenotypic levels. This pattern of association suggests that increase in the plant height and number of leaves per plant may result in higher 10 bulb weight and number of cloves per bulb and ultimately higher bulb yield. Such parallel behavior was also reported by Rahman and Das (1985) and Panthee *et al*., (2006).

Number of leaves per plant per plant was positively and significantly correlated with 10 bulb weight and number of cloves per bulb at genotypic level in all the 3 environment. Genotypic coefficient of correlation values were significant between the number of leaves per plant per plant and days to maturity in E_1 and E_2, whereas, the same trait had a positive and significant phenotypic correlation with days to maturity (E_2), 10 bulb weight (E_2 & E_3), equatorial diameter (E_1 & E_3) and number of cloves per bulb (E_1, E_2 & E_3). The pattern of association suggests that increase in number of leaves per plant may result in 10 bulb weight and number of cloves per bulb and ultimately greater yield per plant. Days to maturity were positively and significantly associated with 10 bulb weight, polar diameter (except E_2) and equatorial diameter at genotypic level in all the three environments. On the contrary, the genotypic associationship between days to maturity and number of cloves was found significant and negative. The phenotypic correlation coefficient was found positive and significant only between days to maturity and 10 bulb weight. This indicating that as more number of cloves leads to late maturity and it is responsible for higher 10 bulb weight which is responsible for higher yield. The most important yield contributing trait like 10 bulb weight was positively and significantly correlated with polar diameter, equatorial diameter and number of cloves per bulb at genotypic and phenotypic levels in all the three environments suggesting the ultimate correlation with bulb yield irrespective of environments. The polar diameter was positively and significantly correlated with equatorial diameter at genotypic and phenotypic levels across the environments, whereas, the association between polar diameter and number of cloves per bulb was opposite to former one.

The correlation between equatorial diameter and number of cloves per bulb was found positive and significant at both genotypic and phenotypic levels under all the three environments which suggest the role of equatorial diameter better shape and yield which is in agreement

Table 1. Genotypic correlation coefficient among different bulb yield components in garlic

Characters		Bulb yield (q/ha)	Plant Height (cm)	No. of leaves	Days to maturity	10 bulb weight (gm)	Polar diameter (cm)	Equatorial Diameter (cm)	No. of clove /bulb
Bulb yield (q/ha)	E1	1.000	0.145	-0.028	-0.181	1.296**	0.372	0.095	1.273**
	E2	1.000	0.271	-0.037	-0.069	0.921**	0.060	0.180	0.920**
	E3		0.335	-0.781	-0.087	1.226**	0.139	0.305	1.349**
Plant Height (cm)	E1		1.000	0.585*	-0.099	0.399	-0.477*	0.071	0.515*
	E2		1.000	0.676*	0.001	0.471*	-0.497*	-0.234	0.663*
	E3		1.000	0.761*	-0.106	0.504*	-0.413*	0.231	0.546*
No. of leaves	E1			1.000	0.487*	0.613*	-0.315	0.460*	0.736*
	E2			1.000	0.518*	0.609*	-0.361	0.353	0.518*
	E3			1.000	0.348	0.419*	-0.180	0.429	0.441*
Days to maturity	E1				1.000	0.626*	0.531*	0.441*	-0.349*
	E2				1.000	0.685*	0.367	0.508*	-0.558*
	E3				1.000	0.479*	0.635*	0.625*	-0.437*
10 bulb weight (gm)	E1					1.000	0.490*	0.787*	1.257**
	E2					1.000	0.522*	0.440*	0.910*
	E3					1.000	0.616*	0.690*	1.085*
Polar diameter (cm)	E1						1.000	0.881*	-0.641*
	E2						1.000	0.509*	-0.593*
	E3						1.000	0.702*	-0.705*
Equatorial Diameter (cm)	E1							1.000	0.768*
	E2							1.000	0.780*
	E3							1.000	0.854*
No. of clove /bulb	E1								1.000
	E2								1.000
	E3								1.000

**,* Significant at 1.0% and 5.0 % respectively; E1- Environment 1 (2006-07), E2- Environment 2 (2007-08) & E3- Environment 3 (2008-09)

Table 2. Phenotypic correlation coefficient among different bulb yield components in garlic

Characters		Bulb yield (q/ha)	Plant Height (cm)	No. of leaves	Days to maturity	10 bulb weight (gm)	Polar diameter (cm)	Equatorial Diameter (cm)	No. of clove /bulb
Bulb yield (q/ha)	E1	1.000	0.032	-0.030	-0.186	1.288**	0.091	0.035	0.922*
	E2	1.000	0.196	-0.079	-0.069	0.990*	0.037	0.015	1.075*
	E3	1.000	0.187	-0.370	-0.068	1.265**	0.005	0.183	1.273**
Plant Height (cm)	E1		1.000	0.471*	-0.119	0.347	-0.162	0.013	0.436*
	E2		1.000	0.470*	0.023	0.457*	-0.232	-0.030	0.583*
	E3			0.628*	-0.060	0.521*	0.145	0.071	0.579*
No. of leaves	E1			1.000	0.328	0.367	-0.116	0.470*	0.563*
	E2			1.000	0.441*	0.486*	-0.253	0.321	0.403*
	E3			1.000	0.114	0.648*	-0.095	0.532*	0.488*
Days to maturity	E1				1.000	0.418*	0.200	0.275	-0.188
	E2				1.000	0.767*	-0.172	0.009	-0.113
	E3				1.000	0.433*	-0.003	0.020	-0.163
10 bulb weight (gm)	E1					1.000	0.627*	0.517*	1.190**
	E2					1.000	0.489*	0.632*	0.925*
	E3					1.000	0.507*	0.543*	0.981*
Polar diameter (cm)	E1						1.000	0.715*	-0.226
	E2						1.000	0.455*	-0.424*
	E3						1.000	0.639*	-0.574*
Equatorial Diameter (cm)	E1							1.000	0.593*
	E2							1.000	0.659*
	E3							1.000	0.508*
No. of clove /bulb	E1								1.000
	E2								1.000
	E3								1.000

**,* Significant at 1.0% and 5.0 % respectively; E1- Environment 1 (2006-07), E2- Environment 2 (2007-08) & E3- Environment 3 (2008-09)

with the earlier reports of Rahman *et al*., (2002) and Hayder *et al*., (2007) in Onion.

Path coefficient analysis provides an effective way of finding out direct and indirect sources of correlations, using genotypic correlations of different plant attributes. Bulb yield was selected as resultant variable and plant height, No of leaves per plant, days to maturity, 10 bulb weight, polar diameter, equatorial diameter and number of cloves per bulb. The results of path analysis are illustrated in Table 3. Maximum positive direct effect on bulb yield was contributed by number of cloves per plant followed by plant height 10 bulb weight and equatorial diameter. On the other hand, maximum negative direct effect was contributed by polar diameter, number of leaves per plant and days to maturity. This means that a slight increase in one of the above traits may directly contribute to bulb yield. The direct effect of plant height on bulb yield was positive showing a path coefficient value of 0.953, 0.974 and 1.962 in E_1, E_2 and E_3 respectively.

The perusal of Table 3 indicated that number of leaves per plant per plant had negative direct effect on bulb yield at all environments. While similar negative values were obtained from indirect effects via days to maturity. This indicating that direct selection for number of leaves per plant may decrease bulb yield but it may used for higher yield keeping the mind of positive indirect effect via 10 bulb weight, polar diameter, equatorial diameter and number of cloves per bulb. Days to maturity had positive direct effect on bulb. Similar positive values were obtained from number of leaves per plant, 10 bulb weight, polar diameter and equatorial diameter. Negative indirect effects were obtained via plant height and number of cloves per bulb. So selection on the basis of days to maturity may be helpful for higher yield but negative indirect effect of number of cloves per bulb must be eliminated. The path coefficient analysis indicated that 10 bulb weight had a positive direct effect. This result suggests that 10 bulb weight is one of the important character for increase of bulb yield directly.

Polar diameter had negative direct effect. Similarly, negative values were obtained from indirect effects via number of cloves. It suggests that direct selection for polar diameter may not be beneficial for higher yield but its positive indirect effect with 10 bulb weight may be utilized for further improvement. The direct effect for equatorial diameter was recorded to be positive. This indicated the importance of the selection on the basis of

Table 3. Path analysis (Genotypic level) showing direct (bold values) and indirect effects among different bulb yield Components in garlic

Characters		Genotypic correlation with Bulb yield	Plant Height (cm)	No. of leaves	Days to maturity	10 bulb weight (gm)	Polar diameter (cm)	Equatorial Diameter (cm)	No. of clove /bulb
Plant Height (cm)	E1	0.045	0.953	-0.014	-0.002	0.256	0.246	-0.569	0.475
	E2	0.271	0.974	-0.226	-0.108	0.188	0.430	-0.182	0.227
	E3	0.335	1.962	-0.081	-0.081	0.304	0.517	0.182	0.529
No. of leaves	E1	-0.028	0.557	-0.254	0.003	0.337	-1.042	0.306	0.520
	E2	0.037	0.711	-0.111	-0.015	0.244	0.312	0.119	0.254
	E3	-0.781	0.513	-0.311	-0.114	0.421	0.237	0.123	0.826
Days to maturity	E1	-0.081	-0.094	0.032	0.022	0.217	1.756	0.476	-0.770
	E2	0.069	-0.001	0.249	0.123	0.374	0.231	0.206	-0.273
	E3	-0.087	-0.207	0.046	0.770	0.481	0.046	0.320	-0.812
10 bulb weight (gm)	E1	0696*	0.380	0.054	-0.001	0.643	1.289	0.606	0.566
	E2	0.721*	0.495	0.984	-0.023	0.700	0.453	0.509	0.703
	E3	0.526*	0.508	0.130	-0.369	1.004	0.417	0.471	0.891
Polar diameter (cm)	E1	-0.372	0.359	0.080	0.012	0.251	-0.306	0.431	-1.414
	E2	0.060	0.022	0.761	0.033	0.209	-0.866	0.396	-0.291
	E3	-0.139	0.026	0.056	0.027	0.317	-0.319	0.316	-0.359
Equatorial Diameter (cm)	E1	-0.095	0.354	-0.051	0.010	0.506	0.930	0.532	0.591
	E2	0.180	0.246	-0.324	-0.001	0.056	0.441	0.779	0.186
	E3	-0.605	0.454	-0.009	0.019	0.090	0.531	0.786	2.927
No. of clove /bulb	E1	1.273**	0.205	0.360	-0.008	0.165	-0.120	0.411	2.205
	E2	1.120**	0.487	0.894	-0.069	0.084	-0.514	0.296	0.890
	E3	0.949*	0.589	0.975	-0.182	0.085	-0.138	0.671	3.429

equatorial diameter for higher bulb yield.

The direct effect of Number of cloves/bulb on bulb yield was positive showing a path coefficient which make it make it highest priority character for direct increase bulb yield. Similar positive indirect effect was recorded via plant height, number of leaves per plant, 10 bulb weight and equatorial diameter.

The present study revealed that 10 bulb weight, equatorial diameter and number of cloves are 3 easily measured characters that would be valuable in selecting for yield improvement.

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