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A Study on Genetic Variability, Character Association and Path Coefficient Analysis in Promising Indigenous Gentoypes of Garlic (*Allium sativum* L.)

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ABSTRACT

*A set of sixteen diverse indigenous genotypes of garlic were studied for the assessment of genetic variability and character association including path coefficient analysis, genetic heritability and genetic advance for twelve yield contributing and economically important traits. A substantial level of genetic diversity was encountered among all the studied genotypes. At both genotypic and phenotypic levels, gross bulb yield was found significantly and positively associated with number of cloves bulb^{-1} (r_p = 0.803**, r_g = 0.807), ascorbic acid (r_p = 0.549**, r_g = 0.572) and weight of 10 uniform cloves (r_p = 0.486**, r_g = 0.487). At the genotypic level, the maximum direct and positive effect on bulb yield was exerted by number of cloves bulb^{-1} (0.684) followed by ascorbic acid (0.399). The maximum negative direct effect on bulb yield was exerted by sulphur content (-0.329) followed by volume of bulb (-0.215), plant height at 90 days after sowing (-0.064), neck thickness (-0.045), TSS (-0.017) and weight of 10 uniform cloves (-0.001). Thus, the present study indicated that the selection for number of cloves bulb^{-1}, dry weight of bulb, circumference of bulb and number of leaves plant^{-1} should be given emphasizes during the selection in garlic.*

Key words: *Genetic variability, Correlation, Path analysis, Garlic.*

INTRODUCTION

Garlic (*Allium sativum* L.), an asexually propagated crop and member of family Amaryllidaceae is an important spice with medicinal properties and is the second most widely cultivated *Allium sp*. after onion (*Allium cepa* L.). India ranks second after China in area (247.52 thousand hectare) and second in production (1259.27 thousand tonnes) of garlic with an average productivity of 5.09 tonnes per hectare[1].

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The major garlic producing states of India are Madhya Pradesh, Odessa, Rajasthan, Karnataka, U. P. and Gujarat. India is one of the garlic exporting countries of the world. The export ranges only 2-3 per cent of the domestic garlic production.

Garlic is a major spice and is regularly consumed almost in every home, not only for culinary purposes but also in home remedies and also used in processing companies, indicating its importance and fairly high demand in the market. Despite the importance of crop, so far very limited breeding work has been done. As a first step of systemic breeding programme, collection and evaluation of germplasm is required. The adequacy of germplasm collection is determined by the amount of genetic variability present in the germplasm. Existence of this natural variation even in respect of the plant parts that is economically important suggests the possibility of improvement in garlic. So far in India few cultivars of garlic are grown.

The economic yield in garlic is obtained from its underground bulb, which is consisted of bulblets, popularly called as cloves. Genetic variability, character association pattern and direct and indirect effects of the yield attributing characters on bulb yield is helpful for effective selection in crop improvement. Knowledge of association of different components together with their relative contributions has immense value in selection. Since estimates of correlation coefficient indicate only the inter relationship of the characters but do not furnish information on the cause and effect, separation of correlation coefficient into the components of direct and indirect effect through path analysis become Important. Correlation and path analysis in respect to various desirable characters in garlic help in isolating promising line for hybridization programme, explore yield potential and quality parameters. The present investigation was therefore undertaken with object to evaluate the correlation and path analysis among materials, consisted of 16 genotypes of garlic with respect to twelve characters.

MATERIALS AND METHODS

The experiment was conducted at Horticulture farms of SKN College of Agriculture, SKNAU; Jobner (Jaipur). A total of sixteen genotypes of garlic collected from the different parts of India for the present investigation (Table 1). Experiment was laid down in randomized block design with three replications. The cloves were planted at a distance of 15 cm row to row and 10 cm plant to plant as per spacing while following standard agronomical practices and observations were recorded for yield and eleven yield contributing traits *viz.* plant height at 90 DAS (cm), number of leaves plant^{-1}, dry weight of bulb (g), number of cloves bulb^{-1}, weight of ten uniform cloves (g), bulb yield (q/ha^{-1}), neck thickness (cm), circumference of bulb (cm), volume of bulb (cc), total soluble solids (%), sulphur content of bulb (%), vitamin 'C' (mg/100g). The data were subjected to analysis of variance adopting standard statistical methods[2]. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated as per standard procedures suggested by Burton[3] and Johanson *et al.*[4]. Heritability was worked out by using the formula as given by Johnson *et al.*[4] and Hanson *et al.*[5]. The genetic advance for each character was calculated by formula as given by Lush[6] and Johanson *et al*.[4] The phenotypic, genotypic and environmental correlation coefficients were calculated from the phenotypic, genotypic and environmental components of variances and co-variances as described by Singh and Choudhary[2]. The direct and indirect effects were estimated through path coefficient analysis as suggested by Wright[7] and elaborated by Dewey and Lu[8].

RESULTS AND DISCUSSION

Mean performance and genetic variability

On perusal of table 2, significant differences among the genotypes were obtained for all the characters, suggesting the presence of a substantial level of variations among the genotypes for all the studied traits. The mean values with respect to characters revealed that, the genotype G-1 was the highest yielder

followed by G-323, G-282 and G-384. The genotype G-1 was also among the top genotypes for the economic traits such as number of cloves per bulb, TSS and ascorbic acid. The genotype G-323 had the highest number of cloves bulb^{-1}and also among the top genotypes for the traits such as plant height at 90 DAS and number of leaves plant^{-1}. The genotype G-282 had the highest weight of ten uniform cloves, ascorbic acid and also more dry weight of bulb, neck thickness, circumference of bulb and sulphur content. The genotype G-384 had the highest circumference and volume of bulb and also more number of cloves bulb^{-1}, neck thickness, TSS and vitamin C. the genotype Sonipat Local had the highest dry weight of bulb also higher in sulphur content. The genotype Kota Local had the highest number of leaves plant^{-1} and sulphur content and also among the top genotypes for the economic traits such as dry weight and circumference of bulb. The genotype Ranikhet Local had the highest neck thickness and also higher in plant height at 90 DAS, circumference of bulb and volume of bulb. These genotypes might be utilized as potent parents in a breeding programme for improving bulb yield and its components.

The assessment of PCV, GCV and heritability helps in estimating the contribution of genes and environment in the expression of any trait, while facilitating a plant breeder for better and effective selection. In the present investigation, for all the studied traits we recorded a higher PCV over the GCV indicting towards the major role of environment the expression of traits (Table 2). High GCV and PCV were observed for volume of bulb (23.20 & 23.31) followed by weight of ten uniform cloves (21.64 & 21.66) in comparison of other characters, indicating the presence of high amount of genetic variability for these traits and suggesting the emphasis on selection for these characters for yield improvement in garlic. Moderated GCV and PCV were observed for dry weight of bulb, neck thickness, number of cloves bulb-^{1}, plant height at 90 DAS and bulb yield. The results of Korla *et al*.[9], Agrawal and Tiwari[10] and Singh *et al.*[11] are also in line with our results. However, the low estimates of PCV and GCV observed for circumference of bulb, number of leaves per plant, ascorbic acid, sulphur content and TSS indicated that the genotypes used had less genetic variability for these characters.

Further, high heritability was observed for bulb yield, weight of 10 uniform cloves, number of cloves per bulb, volume of bulb, ascorbic acid, dry weight of bulb and TSS whereas high heritability along with high GCV was recorded for weight of ten uniform cloves and volume of bulb (Table 2). Thus phenotypic selection might be effective for weight of ten uniform cloves and volume of bulb. Moderate heritability was obtained for neck thickness, plant height at 90 DAS and circumference of bulb. Low value of heritability was recorded for number of leaves per plant and sulphur content. These observations are in confirmatory with Korla *et al*.[9], Agrawal and Tiwari[10], Singh and Chand [12]. High heritability along with high genetic advance as per cent of mean (Table 2) was observed for volume of bulb and bulb yield. In this condition selection will be more effective for these characters. However low heritability and low genetic gain was reported for number of leaves per plant and sulphur content therefore selection in this character would not be much effective.

Character Association

The potential productivity of this crop is basically valued in terms of bulb yield per unit area. Its improvement by direct selection is generally difficult because yield is a complex polygenic character largely influenced by its various component characters as well as by the environment. Hence, it becomes essential to estimate association of yield with component characters and among themselves. The efficiency of selection thus can be increased if it is simultaneously practiced for characters which are correlated with yield.

Table 3 elucidates that in general, the genotypic correlation coefficients were higher than the respective phenotypic correlations which might be from modifying effect of environment on the association of characters at

genotypic level. Selection of yield as such may not be effective since there may be number of genes for bulb yield and bulb yield may be resultant of interaction among its various components. The bulb yield was positively and significantly associated at phenotypic level with number of cloves per bulb, ascorbic acid and weight of 10 uniform. Further, Positive association of plant height at 90 DAS with number of leaves plant^{-1} and volume of bulb; number of leaves plant^{-1} with circumference of bulb and volume of bulb; number of cloves bulb^{-1} with ascorbic acid and weight of ten uniform cloves; weight of ten uniform cloves with ascorbic acid; dry weight of bulb with sulphur content; neck thickness with volume of bulb, circumference of bulb and ascorbic acid; circumference of bulb with volume of bulb and TSS with ascorbic acid, was also recoreded. Similar findings were reported by Kallo *et al.*[13], Shaha *et al.*[14], Kohli and Mahajan[15], Baiday and Tiwari[16], Sonkiya *et al.*[17] in garlic.

Path Coefficient Analysis

The expression of a complex character such as bulb yield depends upon the interplay of a number of component attributes and the path coefficient analysis helps in understanding the direct and indirect effect of various independent attributes on a dependent one. Path coefficient analysis was carried out by taking bulb yield as dependent variable. Direct and indirect effects of various characters on bulb yield revealed an agreement between direction and magnitude of direct effect of various character and correlation with bulb yield. Thus, a significant improvement in bulb yield can be expected through selection in the component traits with high positive direct effects. It is revealed from the table 4 that high order positive direct effect towards bulb yield was exerted by number of cloves bulb^{-1} followed by ascorbic acid, dry weight of bulb, circumference of bulb and number of leaves plant-1. In conformity with present result, Patil *et al*.[18] in onion reported high and direct effect of number of leaves plant^{-1} towards bulb yield. Beside this, weight of 10 uniform cloves, TSS and ascorbic acid showed high and positive indirect effect on bulb yield through number of cloves bulb^{-1}. Number of leaves plant^{-1} and volume of bulb plant^{-1} showed high and positive indirect effect on bulb yield through circumference of bulb our these results are in confirmation with previous studies done by Gupta *et al*.[19] in garlic.

Table 1: List of genotypes

S.No.	Genotypes	Source / origin
1.	Mahadeva	Jhalawar, Rajasthan
2.	Amleta	Jhalawar, Rajasthan
3.	Malaypur	Jhalawar, Rajasthan
4.	Kota local	Kota, Rajasthan
5.	Ranikhet local	Ranikhet, Uttarakhand
6.	Haldwani local	Haldwani,Uttarakhand
7.	G-1	NHRDF,Sub. Centre Karnal
8.	G-41	NHRDF,Sub. Centre Karnal
9.	G-50	NHRDF,Sub. Centre Karnal
10.	G-189	NHRDF,Sub. Centre Karnal
11.	G-282	NHRDF,Sub. Centre Karnal
12.	G-323	NHRDF,Sub. Centre Karnal
13.	G-384	NHRDF,Sub. Centre Karnal
14.	Jaipur local	Jaipur, Rajasthan
15.	Sonipat local	Sonipat,Haryana
16.	Malakapuri	Gwalior, Madhya Pradesh

Table 2: Estimates of genetic parameters of variation for the different characters of garlic genotypes

Characters	Mean	Range	Genotypic Variance	Phenotypic Variance	Genotypic Coefficient of Variance	Phenotypic Coefficient of Variance	Heritability (%)	Genetic Advance	Genetic Advance as per cent of mean (%)
Plant height at 90 DAS (cm)	53.22	41.32 - 71.22	47.76	56.29	12.98	14.10	84.84	13.11	24.64
Number of leaves per plant	7.52	6.73 - 8.06	0.12	0.21	4.54	6.03	56.65	0.53	7.04
Number of cloves per bulb	21.61	17.06-26.44	8.82	8.88	13.75	13.79	99.40	6.10	28.23
Weight of 10 uniform cloves (g)	13.38	9.20-17.80	8.39	8.41	21.64	21.66	99.78	5.96	44.53
Dry weight of bulb (g)	20.51	15.73 - 30.66	13.45	14.63	17.88	18.65	91.91	7.24	35.32
neck thickness (cm)	0.88	0.66 – 1.24	0.02	0.02	14.61	15.83	85.15	0.24	27.77
Circumference of bulb (cm)	12.28	10.42 - 14.02	1.00	1.19	8.16	8.90	83.98	1.89	15.40
Volume of bulb (cc)	34.64	22.26 - 47.26	64.61	65.21	23.20	23.31	99.08	16.48	47.58
Total soluble solids (%)	41.79	39.77 - 43.19	1.00	1.11	2.39	2.52	89.91	1.95	4.67
Sulphur content (%)	0.33	0.31 - 0.35	0.00	0.00	2.63	4.07	41.93	0.01	3.51
Ascorbic acid (mg/100g)	11.05	9.57 - 11.48	0.21	0.22	4.13	4.28	93.49	0.91	8.24
Bulb yield (q/ha)	123.84	100.56 - 151.80	231.31	231.76	12.28	12.29	99.80	31.30	25.27

Table 3: Phenotypic (P) and genotypic (G) correlation coefficients between different characters in garlic

Characters		Plant height at 90 days after sowing(cm)	Number of leaves per Plant	Number of cloves per bulb	Weight of 10 uniform cloves (g)	Dry weight of bulb (g)	Neck thickness (cm)	Circumference of bulb (cm)	Volume of bulb (cc)	Total soluble solids (%)	Sulphur content (%)	Ascorbic acid (mg/100g)	Bulb yield (q/ha)
Plant height at 90 DAS (cm)	**P**	1.0000	0.5021**	-0.4148**	-0.4213**	-0.1700	-0.0753	0.2728	0.3462*	-0.3432*	-0.3833**	-0.6045**	-0.4709**
	G	1.0000	0.5721	-0.4540	-0.4618	-0.1954	-0.0765	0.3131	0.3735	-0.4001	-0.5217	-0.6967	-0.5071
Number of leaves plant^{-1}	**P**		1.0000	-0.0327	0.1531	-0.0786	0.0365	0.4376**	0.3610*	-0.1000	-0.0106	-0.0572	-0.0794
	G		1.0000	-0.0648	0.2025	-0.0900	0.0589	0.6499	0.4661	-0.0831	0.1592	-0.1289	-0.0984
Number of cloves Bulb^{-1}	**P**			1.0000	0.3881**	0.0403	-0.1737	-0.0203	-0.0662	0.2101	0.1812	0.3910**	0.8032**
	G			1.0000	0.3907	0.0473	-0.1897	-0.0256	-0.0696	0.2246	0.2795	0.4018	0.8070
Weight of 10 uniform cloves (g)	**P**				1.0000	0.1027	0.0120	0.0494	-0.2757	0.2683	0.1894	0.4507**	0.4865**
	G				1.0000	0.1041	0.0157	0.0574	-0.2773	0.2803	0.3159	0.4668	0.4872
Dry Weight of bulb (g)	**P**					1.0000	-0.1270	-0.1277	-0.1604	0.1051	0.4900**	-0.2212	0.0051
	G					1.0000	-0.1525	-0.1310	-0.1602	0.0810	0.8052	-0.2295	0.0068
Neck thickness (cm)	**P**						1.0000	0.4908**	0.4971**	0.1039	0.1270	0.4149**	-0.0457
	G						1.0000	0.5690	0.5470	0.1159	0.2199	0.4810	-0.0444
Circumference of bulb (cm)	**P**							1.0000	0.6873**	-0.1053	0.1103	0.1267	0.0462
	G							1.0000	0.7555	-0.1497	0.1346	0.1138	0.0529
Volume of bulb (cc)	**P**								1.0000	0.0767	-0.0709	0.0882	-0.0588
	G								1.0000	0.0785	-0.0931	0.0895	-0.0587
Total soluble solids (%)	**P**									1.0000	0.2237	0.2980*	0.1289
	G									1.0000	0.3773	0.3575	0.1363
Sulphur content (%)	**P**										1.0000	0.1504	0.1759
	G										1.0000	0.1737	0.2703
Ascorbic acid (mg/100g)	**P**											1.0000	0.5496**
	G											1.0000	0.5729

*Significant at p=0.05 or at 5 % and **Significant at p=0.01 or at 1%

Table 4: Phenotypic (P) and genotypic (G) path coefficients of various characters on bulb yield of garlic

Characters		Plant height at 90 days after sowing(cm)	Number of leaves plant^{-1}	Number of cloves bulb^{-1}	Weight of 10 uniform cloves (g)	Dry weight of bulb (g)	Neck thickness (cm)	Circumference of bulb (cm)	Volume of bulb (cc)	Total soluble solids (%)	Sulphur content (%)	Ascorbic acid (mg/ 100g)	Correlation with bulb yield
Plant height at 90 days after sowing (cm)	**P**	**0.0781**	-0.0849	-0.2628	-0.0893	-0.0058	0.0083	0.0078	0.0352	0.0525	-0.0138	-0.1962	**-0.4709**
	G	**-0.0649**	0.0113	-0.3105	0.0007	-0.0626	0.0034	0.0955	-0.0806	0.0072	0.1719	-0.2784	**-0.5071**
Number of leaves plant^{-1}	**P**	0.0392	**-0.1691**	-0.0207	0.0325	-0.0027	-0.0040	0.0124	0.0367	0.0153	-0.0004	-0.0186	**-0.0794**
	G	-0.0371	**0.0197**	-0.0443	-0.0003	-0.0288	-0.0027	0.1982	-0.1006	0.0015	-0.0525	-0.0515	**-0.0984**
Number of cloves bulb^{-1}	**P**	-0.0324	0.0055	**0.6335**	0.0822	0.0014	0.0190	-0.0006	-0.0067	-0.0321	0.0065	0.1269	**0.8032**
	G	0.0295	-0.0013	**0.6840**	-0.0006	0.0152	0.0085	-0.0078	0.0150	-0.0040	-0.0921	0.1606	**0.8070**
Weight of 10 uniform cloves (g)	**P**	-0.0329	-0.0259	0.2459	**0.2119**	0.0035	-0.0013	0.0014	-0.0280	-0.0410	0.0068	0.1463	**0.4865**
	G	0.0300	0.0040	0.2673	**-0.0015**	0.0334	-0.0007	0.0175	0.0599	-0.0050	-0.1041	0.1865	**0.4872**
Dry weight of bulb (g)	**P**	-0.0133	0.0133	0.0256	0.0218	**0.0340**	0.0139	-0.0036	-0.0163	-0.0161	0.0176	-0.0718	**0.0051**
	G	0.0127	-0.0018	0.0324	-0.0002	**0.3206**	0.0069	-0.0400	0.0346	-0.0015	-0.2653	-0.0917	**0.0068**
Neck thickness (cm)	**P**	-0.0059	-0.0062	-0.1100	0.0026	-0.0043	**-0.1097**	0.0140	0.0505	-0.0159	0.0046	0.1346	**-0.0457**
	G	0.0050	0.0012	-0.1297	0.0000	-0.0489	**-0.0450**	0.1736	-0.1181	-0.0021	-0.0724	0.1922	**-0.0444**
Circumference of bulb (cm)	**P**	0.0213	-0.0740	-0.0129	0.0105	-0.0043	-0.0538	**0.0284**	0.0698	0.0161	0.0040	0.0411	**0.0462**
	G	-0.0203	0.0128	-0.0175	-0.0001	-0.0420	-0.0256	**0.3050**	-0.1631	0.0027	-0.0443	0.0455	**0.0529**
Volume of bulb (cc)	**P**	0.0270	-0.0611	-0.0419	-0.0584	-0.0055	-0.0545	0.0195	**0.1016**	-0.0117	-0.0025	0.0286	**-0.0588**
	G	-0.0243	0.0092	-0.0476	0.0004	-0.0514	-0.0246	0.2305	**-0.2159**	-0.0014	0.0307	0.0357	**-0.0587**
Total soluble solids (%)	**P**	-0.0268	0.0169	0.1331	0.0568	0.0036	-0.0114	-0.0030	0.0078	**-0.1529**	0.0080	0.0967	**0.1289**
	G	0.0260	-0.0016	0.1536	-0.0004	0.0260	-0.0052	-0.0457	-0.0169	**-0.0179**	-0.1243	0.1428	**0.1363**
Sulphur Content (%)	**P**	-0.0299	0.0018	0.1148	0.0401	0.0167	-0.0139	0.0031	-0.0072	-0.0342	**0.0359**	0.0488	**0.1759**
	G	0.0339	0.0031	0.1912	-0.0005	0.2582	-0.0099	0.0411	0.0201	-0.0068	**-0.3295**	0.0694	**0.2703**
Ascorbic acid (mg/100g)	**P**	-0.0472	0.0097	0.2477	0.0955	-0.0075	-0.0455	0.0036	0.0090	-0.0456	0.0054	**0.3245**	**0.5496**
	G	0.0452	-0.0025	0.2749	-0.0007	-0.0736	-0.0217	0.0347	-0.0193	-0.0064	-0.0572	**0.3996**	**0.5729**

Residual effect : Phenotypic = 0.4959 and Genotypic = 0.4974

CONCLUSION

On the basis of the results obtained in present investigation, it may be concluded that there is highly significant differences among the genotypes for all the characters. The genotype G-1 was the highest yielder followed by G-323, G-282 and G-384. The correlation of bulb yield was positive and significant at phenotypic level with number of cloves per bulb, ascorbic acid and weight of 10 uniform cloves. It is revealed from the result that high order positive direct effect towards bulb yield was exerted by number of cloves per bulb followed by ascorbic acid, dry weight of bulb, circumference of bulb and number of leaves per plant. It may be concluded that the characters like number of cloves per bulb, ascorbic acid, dry weight of bulb, circumference of bulb and number of leaves per plant may be of merit value when making selection for desirable genotypes.

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