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Short Communication

Correlation and path analysis studies in garlic (*Allium sativum* L.)

SS Sandhu, PS Brar, RK Dhall* and Neena Chawla

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Garlic (*Allium sativum* L.) is one of the most important bulb vegetable grown and used as flavoring agent for foods. At national level, it is the second most important cultivated bulb crop after onion in area and production (Shankar *et al.* 1997). Garlic products have become popular in recent years and a variety of culinary and pharmaceutical preparations are now available in market. In the Asian continent, people use fresh leaves of garlic as salad and pickle is also prepared from garlic cloves (Pandey and Singh 1987). Garlic has several medicinal values such as antibacterial, antifungal, antiviral, antioxidant and anticancer properties (Harris *et al.* 2001). Effective improvement programme in vegetative propagated crop depends upon the availability of sufficient genetic variability, so that selection could be done. The information available on the relative importance of component characters of quality in this crop is limited. It is desirable to assess the importance as well as degree of association of various quantitative characters in order to initiate effective selection programme for genetic improvement of garlic. The present study was, therefore, undertaken to find out the genotypic and phenotypic correlations between various characters and their direct and indirect effect on allicin content of garlic.

The experimental material consisted of forty genotypes of garlic selected from a diverse collection of germplasm, maintained at the Vegetable Research Farm of Department of Vegetable Science, PAU, Ludhiana. Planting of cloves was done at a spacing of 15×7.5 cm in first fortnight of October. The recommended agro-practices were followed to ensure a healthy crop growth and development. 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., leaf length (cm), leaf width (cm), number of leaves per plant, scape length (cm), bulb diameter (mm), number of cloves/bulb, clove weight (g), bulb weight (g), number of bulbils/ umbel, bulbil size, dry matter (%), ash content (%), crude protein (%)was estimated by Kjeldahl method of nitrogen estimation (McKenzie and Wallace, 1954), total soluble sugars (%) was estimated using the method given by Dubios *et al.,* (1956), alchol insoluble insolids (%) (Woodward, 1972) and allicin content (%) estimated by a method adopted from Jafarian *et al.* (2003). Genotypic and phenotypic correlation coefficients were worked out using the formulae suggested by Al-Jibourie *et al*., (1958) and path analysis was carried out as suggested by Dewey and Lu (1959) so as to study the direct and indirect contribution of component characters on bulb yield per plot of garlic genotypes.

The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. The phenotypic correlation coefficients among different characters showed that allicin content had positive and significant association with scape length (0.4411), number of clove per bulb (0.4195), leaf width (0.3782), crude protein (0.3708) and bulb weight (0.2590), while non-significant and negative correlations with number of leaves per plant, bulbil size, number of bulbils per umbel, leaf length, total sugars and dry matter (Table 1). From correlation matrix of different characters, it is evident that genotypic coefficients of correlation in general were higher in magnitude than the corresponding phenotypic coefficients of correlation (Table 1). This indicates that there was an inherent association among various characters under study, which was depressed due to environmental influence and ultimately resulted in low phenotypic expression of the correlation. Estimation of genotypic correlation coefficients indicated that allicin content had significant positive association with scape length (0.4537), leaf width (0.3991), number of cloves per bulb (0.4499), crude protein (0.3831) and bulb weight (0.2630), while non-significant and negative

Department of Vegetable Science, Punjab Agricultural University, Ludhiana-141004, Punjab
*Corresponding author, Email: dhallrk2007@rediffmail.com

Table 1: Phenotypic (P) and genotypic (G) coefficients of correlation among different traits in different genotypes of garlic

Traits		NL	NC	BD	BUL S	N BUL	LL	CW	LW	SL	BW	DM	AC	AIS	TS	CP	A
NL	G	1.000	-0.0910	-0.0496	-0.1758	-0.0729	0.2286*	-0.0647	-0.0702	0.1125	-0.0431	-0.1585	-0.2468*	0.0106	0.1316	-0.1066	-0.0749
	P	1.000	-0.0728	-0.0535	-0.1614	-0.0602	0.1983	-0.0596	-0.0458	0.1182	-0.0508	-0.1462	-0.2163	0.0005	0.1239	-0.0749	-0.0677
NC	G		1.000	0.7217**	0.2552*	0.2875**	-0.0281	0.0238	0.3285**	0.3644**	0.6350**	0.0685	0.3563**	0.3642**	0.1958	0.3911**	0.4466**
	P		1.000	0.6685**	0.2342*	0.2615*	-0.0327	0.0394	0.2862**	0.3347**	0.5878**	0.0660	0.3033**	0.3443**	0.1849	0.3219**	0.4195**
BD	G			1.000	.3346**	0.1881	0.1493	0.3978**	0.1450	0.2858**	0.6200**	0.0517	0.3523**	0.2868**	0.1578	0.2933**	0.3819**
	P			1.000	.3243**	0.1833	0.1458	0.3696**	0.1370	0.2683*	0.6249**	0.0355	0.3251**	0.2814*	0.1564	0.2369*	0.3739**
BULS	G				1.000	0.1588	0.0124	0.5195**	0.1392	0.1095	0.5558**	0.0428	0.0814	0.1004	0.0540	0.0326	0.0147
	P				1.000	0.1478	0.0129	0.4810**	0.1283	0.1020	0.5396**	0.0423	0.0732	0.1035	0.0534	0.0146	0.0148
NBUL	G					1.000	-0.0784	0.3589**	-0.0045	-0.0690	0.3249**	-0.1028	0.1793	0.0436	-0.2464**	-0.1012	0.1757
	P					1.000	-0.0741	0.3283**	-0.0040	-0.0709	0.3178**	-0.1023	0.1543	0.0360	-0.2434**	-0.0785	0.1708
LL	G						1.000	0.3780**	0.1489	-0.0712	0.2416*	-0.3123**	-0.0324	0.0492	0.1484	-0.0095	0.1479
	P						1.000	0.3321**	0.1331	-0.0673	0.2335*	-0.2902**	-0.0191	0.0526	0.1457	-0.0287	0.1458
CW	G							1.000	-0.1005	-0.2702*	0.6639**	-0.2821*	0.0283	0.0120	0.0004	0.0909	0.0501
	P							1.000	-0.1033	-0.2348*	0.6179**	-0.2373*	0.0233	0.0077	0.0001	0.0780	0.0450
LW	G								1.000	0.3894**	0.2034	0.2957**	0.3466**	0.1503	0.3008**	-0.1073	0.3991**
	P								1.000	0.3628**	0.1881	0.2589*	0.2852*	0.1369	0.2867**	-0.0777	0.3782**
SL	G									1.000	0.1624	0.1154	0.0190	0.0968	0.3583**	0.2733*	0.4537**
	P									1.000	0.1512	0.1083	0.0087	0.0842	0.3501**	0.2325*	0.4411**
BW	G										1.000	-0.1098	0.1751	0.3359**	0.1024	0.3264**	0.2630*
	P										1.000	-0.1143	0.1768	0.3296**	0.1019	0.2674*	0.2590*
DM	G											1.000	0.2055	-0.0684	0.0277	0.0121	-0.0550
	P											1.000	0.1839	-0.0544	0.0263	0.0196	-0.0523
AC	G												1.000	0.0786	-0.0737	-0.1290	0.2773*
	P												1.000	0.0766	-0.0652	-0.0845	0.2506*
AIS	G													1.000	-0.1194	0.2711*	0.4053**
	P													1.000	-0.1170	0.2279*	0.4003**
TS	G														1.000	0.0147	0.0657
	P														1.000	0.0382	0.0661
CP	G															1.000	0.3831**
	P															1.000	0.3708**

NL-Number of leaves, NC-Number of cloves, BD- Bulb Diameter, BUL S-Bulbil Size, N BUL- Number of bulbils, LL- Leaf length, CW- Clove weight, LW- Leaf width, SL-Scape length, BW-Bulb weight, DM-Dry matter, AC- Ash content, AIS- Alcohol insoluble solids, TS-Total sugars, CP- Crude protein, A- Allicin content; *and **- Significant at 5% and 1% level of significance, respectively

correlations was observed with number of leaves per plant, bulbil size, number of bulbils per umbel, leaf length, total sugars and dry matter.

Although correlation coefficient indicates the nature of association among the traits, path coefficient analysis splits the values into direct and indirect effects so as to measure the relative importance of causal factors involved. Path coefficient analysis is useful in finding out direct and indirect causes of associations and allows a precise perception of specific forces acting to produce a given correlation. In present investigations, the phenotypic as well as genotypic correlations were partitioned into direct and indirect effects with the help of path analysis (Table 2). The path coefficient analysis on phenotypic basis revealed that among the characters studied, seven characters exhibited direct and positive effect and seven characters showed negative direct effects on allicin content, respectively. The estimates regarding phenotypic path analysis revealed that clove weight has maximum positive direct effect (3.5490) on allicin content followed by number of clove per bulb (3.182) and scape length (1.452). On the other hand negative direct effect of bulb diameter (-1.765), bulbil size (-0.669), number of bulbils per umbel (-0.825), leaf width (-0.100) and bulb weight (-2.584) was observed on allicin. Maximum positive indirect effect of clove weight (3.182) via bulb weight was observed on allicin content. The path coefficient analysis on phenotypic basis revealed that leaf width has minimum direct negative effect (-0.100) on allicin content followed by bulb diameter (-1.765) and bulb weight (-2.584). Leaf width showed minimal negative direct effect on allicin content but showed positive indirect effect through number of leaves, number of bulbils, and clove weight. Path analysis revealed that clove weight, number of cloves per bulb, scape length, number of leaves per plant are the important allicin component traits. Also, selection for more bulb weight and bulb diameter may indirectly lead to increase in allicin content.

The estimates of genotypic path analysis (Table 2) revealed that scape length (0.3998) has maximum positive direct effect on allicin, followed by alcohol insoluble solids (0.2966), clove weight (0.2610), leaf width (0.2545) and number of cloves per bulb (0.1558) while, negative direct effect of total sugar (-.0795), number of leaves per plant (-.0910) and dry matter(-0.1187) was observed on allicin.The residual (unexplained) variation in the path analysis came out to be 0.2311 based on genotypic correlations and 0.4472 based on phenotypic correlations among the characters studied for all the genotypes. This residual variation signified that there was still unexplained and unaccounted variations left among the genotypes which could not be explained by the above traits studied. To explain the same, some more morphological and biochemical characters are needed to be studied. Thus, path analysis revealed that increase in scape length and number of cloves per bulb will be reflected in an increase in allicin content. Also, selection for higher clove weight per plant may lead to increase in allicin content. Moreover, increase in bulb diameter and leaf width would results in decrease in allicin content.

Table 2: Estimates of direct and indirect effects of significant traits on yield/plot in garlic

Trait		NL	NC	BD	BUL S	N BUL	LL	CW	LW	SL	BW	DM	AC	AIS	TS	CP	CCA
NL	G	-0.0910	-0.0113	-0.0042	0.0220	-0.0086	0.0247	-0.0155	-0.0117	0.0472	0.0171	0.0174	-0.0294	0.0001	-0.0098	-0.0146	-0.0749
	P	0.0047	-0.2897	0.0876	0.1176	0.0601	0.0053	-0.2296	0.0071	0.1634	0.1114	-0.0621	-0.0252	0.0066	-0.0772	0.0451	-0.0677
NC	G	0.0066	0.1558	0.0530	-0.0320	0.0372	-0.0041	0.0103	0.0729	0.1338	-0.1977	-0.0078	0.0413	0.1021	-0.0147	0.0628	0.4466**
	P	-0.004	3.1822	-1.2742	-0.1707	-0.2373	-0.0007	0.0845	-0.0331	0.5294	-1.6412	0.0269	0.0364	0.2251	-0.1149	-0.1656	0.4195**
BD	G	0.0049	0.1042	0.0792	-0.0442	0.0261	0.0181	0.0964	0.0349	0.1073	-0.2102	-0.0042	0.0442	0.0834	-0.0124	0.0462	0.3819**
	P	-0.0002	2.2966	-1.7655	-0.2238	-0.1552	0.0035	1.4117	-0.0146	0.4152	-1.6024	0.0203	0.0360	0.1773	-0.0926	-0.1242	0.3739**
BULS	G	0.0147	0.0365	0.0257	-0.1364	0.0210	0.0016	0.1255	0.0327	0.0408	-0.1815	-0.0050	0.0100	0.0307	-0.0042	0.0028	0.0147
	P	-0.0008	0.8121	-0.5908	-0.6690	-0.1311	0.0003	1.8436	-0.0140	0.1591	-1.4364	0.0168	0.0083	0.0620	-0.0317	-0.0138	0.0148
NBUL	G	0.0055	0.0407	0.0145	-0.0202	0.1422	-0.0092	0.0857	-0.0010	0-.0284	-0.1069	0.0121	0.0210	0.0107	0.0194	-0.0153	0.1757
	P	-0.0003	0.9149	-0.3321	-0.1062	-0.8253	-0.0018	1.2737	0.0005	-0.1002	-0.8398	-0.0403	0.0183	0.0269	0.1446	0.0428	0.1708
LL	G	-0.0180	-0.0051	0.0116	-0.0018	-0.0105	0.1243	0.0867	0.0339	-0.0269	-0.0786	0.0344	-0.0026	0.0156	-0.0116	-0.0056	0.1479
	P	0.0011	-0.0894	-0.2636	-0.0083	0.0647	0.0232	1.3415	-0.0150	-0.1035	-0.6244	-0.1224	-0.0033	0.0304	-0.0871	0.0040	0.1458
CW	G	0.0054	0.0061	0.0293	-0.0656	0.0467	0.0413	0.2610	-0.0263	-0.0938	-0.2079	0.0282	0.0032	0.0023	0.0000	0.0152	0.0501
	P	-0.0003	0.0758	-0.7023	-0.3475	-0.2962	0.0088	3.5490	0.0101	-0.3925	-1.7157	-0.1106	0.0029	0.0074	-0.0002	-0.0385	0.0450
LW	G	0.0042	0.0446	0.0109	-0.0175	-0.0006	0.0166	-0.0270	0.2545	0.1450	-0.0633	-0.0307	0.0388	0.0406	-0.0228	-0.0152	0.3991**
	P	-0.0003	1.0454	-0.2560	-0.0931	0.0037	0.0035	-0.3567	-0.1007	0.5658	-0.5257	0.1159	0.0354	0.0929	-0.1765	0.0454	0.3782**
SL	G	-0.0107	0.0522	0.0213	-0.0139	-0.0101	-0.0084	-0.0613	0.0923	0.3998	-0.0509	-0.0128	0.0012	0.0250	-0.0278	0.0454	0.4537**
	P	0.0005	1.1594	-0.5045	-0.0733	0.0569	-0.0017	-0.9588	-0.0392	1.4529	-0.4197	0.0452	0.0019	0.0598	-0.2102	-0.1157	0.4411**
BW	G	0.0046	0.0916	0.0495	-0.0736	0.0452	0.0290	0.1612	0.0479	0.0605	-0.3364	0.0136	0.0241	0.0977	-0.0081	0.0522	0.2630*
	P	-0.0002	2.0208	-1.0947	-0.3718	-0.2682	0.0056	2.3561	-0.0205	0.2360	-2.5844	-0.0430	0.0179	0.2076	-0.0601	-0.1382	0.2590*
DM	G	0.0133	0.0103	0.0028	-0.0058	-0.0145	-0.0361	-0.0619	0.0659	0.0433	0.0385	-0.1187	0.0250	-0.0161	-0.0021	0.0038	-0.0550
	P	-0.0007	0.2181	-0.0913	-0.0286	0.0848	-0.0072	-1.0010	-0.0298	0.1676	0.2838	0.3921	0.0210	-0.0423	-0.0163	-0.0051	-0.0523
AC	G	0.0197	0.0473	0.0258	-0.0100	0.0219	-0.0024	0.0061	0.0726	0.0035	-0.0595	-0.0218	0.1361	0.0227	0.0052	-0.0165	0.2773*
	P	-0.0012	1.1338	-0.6219	-0.0545	-0.1480	-0.0008	0.1004	-0.0349	0.0275	-0.4524	0.0806	0.1022	0.0486	0.0432	0.0546	0.2506*
AIS	G	0.0000	0.0537	0.0223	-0.0141	0.0051	0.0065	0.0020	0.0348	0.0337	-0.1109	0.0065	0.0104	0.2966	0.0093	0.0445	0.4053**
	P	0.0001	1.1590	-0.5064	-0.0671	-0.0360	0.0011	0.0426	-0.01 51	0.1406	-0.8681	-0.0268	0.0080	0.6182	0.0700	-0.1148	0.4003**
TS	G	-0.0113	0.0288	0.0124	-0.0073	-0.0346	0.0181	0.0000	0.0730	0.1399	-0.0343	-0.0031	-0.0089	-0.0347	-0.0795	0.0074	0.0657
	P	0.0006	0.6231	-0.2786	-0.0361	0.2034	0.0034	0.0015	-0.0303	0.5205	-0.2647	0.0109	-0.0075	-0.0738	-0.5867	-0.0199	0.0661
CP	G	0.0068	0.0502	0.0188	-0.0020	-0.0112	-0.0036	0.0204	-0.0198	0.0929	-0.0900	-0.0023	-0.0115	0.0676	-0.0030	0.1951	0.3831**
	P	-0.0005	1.2447	-0.5178	-0.0218	0.0835	-0.0002	0.3227	0.0108	0.3971	-0.8434	0.0047	-0.0132	0.1676	-0.0276	-0.4234	0.3708**

NL-Number of leaves, NC-Number of cloves, BD- Bulb Diameter, BUL S-Bulbil Size, N BUL- Number of bulbils, LL- Leaf length, CW- Clove weight, LW- Leaf width, SL-Scape length, BW-Bulb weight, DM-Dry matter, AC- Ash content, AIS- Alcohol insoluble solids, TS-Total sugars, CP- Crude protein, CCA- Coefficient of correlation for Allicin content; Unexplained variation P= 0.4472, G = 0.2311; *and **- Significant at 5% and 1% level of significance

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