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

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Abstract
Character association and path analysis in one fifty genotypically diverse indigenous genotypes of garlic (*Allium sativum* L.) were evaluated at Vegetable Research Station, Junagadh Agricultural University, Junagadh during the year 2016-17 for fifteen important characters. Bulb yield (kg/ha) exhibited positive and significant association with plant height, number of leaves per plant, days to maturity, bulb polar diameter, bulb weight, number of cloves per bulb, clove length and pseudo stem height at both genotypic and phenotypic levels. Path coefficient analysis provides an effective means of critical examination of specific force of action to produce a given correlation and measure the relative importance of each factor. In this analysis bulb yield was taken as dependent variable and rest of the characters were considered as independent variables. The phenotypic path coefficient analysis revealed that positive and maximum direct effect on bulb yield was exerted by number of cloves per bulb followed by bulb weight, total soluble solids, days to maturity, pseudo stem height, number of leaves per plant, leaf width at middle portion, plant height and clove weight. These characters turned out to be major components of bulb yield. Considerable amount of indirect effects *via* bulb weight was observed for bulb polar diameter, number of cloves per bulb, clove weight, clove length and pseudo stem height.

Keywords: Garlic (*Allium sativum* L.), correlation, path - analysis, yield

Introduction
Garlic (*Allium sativum* L.) belonging to the family *Alliaceae* is one of the most important remunerative bulbous spice and medicinal crop of *Allium* group next to onion. Garlic has been originated from Central Asia and it is grown throughout the world. "*Allium*" is the largest and the most important representative genus of the *Alliaceae* family that comprises 700 species, widely distributed in the Northern hemisphere, North America, North Africa, Europe and Asia (Tsiaganis *et al.*, 2006) [12]. The major garlic growing countries are China, Spain, Korea, Egypt and U.S.A. China ranks first in area and production followed by India and Korea republic (Kumar *et al*., 2017) [5].
Garlic has a chromosome number of 2n=2x=16. It is an herbaceous annual bulb producing crop. The edible underground stem is the composite bulb made up of numerous smaller bulbs called cloves. Leaves have solid thin blades. Garlic is an obligate apomitic crop hence vegetative reproduction occurs. Even though some varieties produce flowers but these flowers do not set seeds. There are some varieties which produce vegetative bulbs on the top called bulbils. They are also used for propagation in some cases.
Yield being a complex polygenic trait is dependent on a number of attributing traits and association among the component character is a pre-requisite to execute effective selection programme. In order to increase the potential of garlic varieties for bulb yield, an understanding of the relationship among different plant characters is of immense importance. Besides, knowledge about the direct contribution of different component characters to yield would be highly useful for formulating a selection programme. Therefore, the present study was undertaken to provide information on the effect of the selection for one character on the direction and magnitude of change in others when simultaneous improvement is sought in more than one attribute.

Materials and Methods
The present investigation was carried out during *Rabi* 2016-17 at Vegetable research Station, Junagadh Agricultural University, Junagadh. The experimental material comprised of 150 genotypes along with four checks namely GG - 4, G - 282, GJG – 5 and GAG – 6 collected from Directorate of Onion and Garlic Research (DOGR), Rajgurunagar, Pune through Vegetable Research Station, Junagadh Agricultural University, Junagadh. The experiment was laid out in Augmented Randomized Block Design (ABRD). Each genotype was

Accommodated in a plot of 1.5 × 1.0 m size by keeping 15 × 10 cm distance between two rows and two plants, respectively. All the recommended cultural practices were adopted to raise a healthy crop. Data were recorded on randomly selected ten plants with respect to characters namely plant height (cm), number of leaves per plant, leaf length (cm), leaf width at middle portion (cm), days to maturity (days), bulb equatorial diameter (cm), bulb polar diameter (cm), bulb weight (g), number of cloves per bulb, clove weight (g), clove length (cm), bulb yield (kg/ha), total soluble solids (%), neck thickness (cm) and pseudo stem height (cm). Data were statistically analyzed to estimate genotypic and phenotypic correlation (Al-jibouri *et al*., 1958) [1] and path coefficient analysis (Dewey and Lu, 1959) [3].

Result and discussion

Correlation Coefficient

In general, the genotypic correlation coefficients were higher than the respective phenotypic correlations (Table 1) which might be from modifying effect of environment on the association of characters at genotypic level.

Bulb yield was found to be significantly and positively correlated at both genotypic and phenotypic levels with plant height, number of leaves per plant, days to maturity, bulb polar diameter, bulb weight, number of cloves per bulb, clove length and pseudo stem height. This indicated that these attributes were more influencing the bulb yield in garlic and therefore, were important for bringing improvement in bulb yield. Such positive interrelationships between bulb yield and plant height, number of leaves per plant, bulb polar diameter and bulb weight was noted by Singh *et al*. (2011) [10], Singh *et al*. (2013) [11], Sharma *et al*. (2016) [7], Prajapati *et al.* (2016) [7], Sangeeta *et al.* (2016) [8], Chotalia and Kulkarni (2017) [2] and Kumar *et al*. (2017) [5] Bulb equatorial diameter and bulb polar diameter had positive and significant association with each other at both the levels. These were also found to have significant association with bulb weight and clove length which indicated that improvement in one will bring the improvement in the other character, bulb polar diameter also had significant association with bulb yield. Clove weight and clove length were also found to have positive and significant association with each other, while clove weight had negative and significant association with number of cloves per bulb, hence selection for one character has the opposite effect on the other. Number of leaves per plant had positive association with bulb weight, number of cloves per bulb and clove length. It is similar to the results obtained by Esho (2015) [1] and Prajapati *et al.* (2016) [7]. Total soluble solids had negative and significant association with number of leaves per plant which showed that improvement of one character had the negative effect on the other character. Similar results were obtained by Kumar *et al*. (2015) [6]. Days to maturity also had significant and positive correlation with leaf width at middle portion which indicated that these traits are interrelated with each other and improvement in one character will bring significant improvement in the other.

Table 1: Phenotypic (P) and genotypic (G) correlation coefficients among 15 characters in garlic.

Characters		Plant height	Number of leaves per plant	Leaf length	Leaf width at middle portion	Days to maturity	Bulb equatorial diameter	Bulb polar diameter	Bulb weight	Number of cloves per bulb	Clove weight	Clove length	Total soluble solids	Neck thickness	Pseudo stem height	Bulb yield
1	G	1.000	-0.0936	0.7494**	-0.0909	0.3260**	0.3471**	-0.0483	0.3504**	0.5810**	0.1267	0.2779**	0.7945**	0.7085**	0.7802**	0.5587**
	P	1.000	-0.0490	0.6281**	0.0181	-0.0785	0.1035	0.1243	0.1949*	0.2612**	0.1803*	0.1194	0.1117	0.2378**	0.5423**	0.2140**
2	G		1.0000	0.2528**	0.2528*	1.2050**	-0.1341	0.4159**	0.2822**	0.4325**	0.1685*	0.1958*	-0.5932*	0.1574**	0.2036*	0.4011**
	P		1.0000	-0.0061	0.1529	0.3169**	0.0682	0.2978**	0.2367**	0.1994**	0.0859	0.1493	-.2460**	-0.0084	0.2039*	0.3021**
3	G			1.0000	-0.1117	0.4359**	0.3257**	0.0896	0.2209**	0.1852**	0.0643	0.3462**	0.5994*	0.0996	0.4187**	0.2036*
	P			1.0000	0.0412	0.0221	0.1080	0.1670*	0.1141	0.1817**	0.1096	0.0929	0.0937	0.1952*	0.2640**	0.1039
4	G				1.0000	1.1121**	0.3212**	0.3673**	0.4392**	0.0088	0.4163**	0.5118**	0.2672**	0.4304**	0.1742*	0.1357
	P				1.0000	0.2649*	0.1629*	0.4733**	0.3909**	0.0183	0.3597**	0.2744**	-0.0137	0.3601**	0.0855	0.1263
5	G					1.0000	0.2676**	1.5515**	1.1191**	0.4507**	0.5099**	0.7296**	-.3916**	0.1995*	0.2738**	0.5029**
	P					1.0000	0.0848	0.4065**	0.3030**	0.0769	0.1112	0.1428	-0.0404	0.1619*	0.1209	0.2958**
6	G						1.0000	0.2649**	0.3906**	0.4115**	0.2295**	0.7074**	-0.0891	0.1246	0.3378**	0.1495
	P						1.0000	0.2550**	0.2895**	0.2319**	0.1224	0.0981	-0.1071	0.0855	0.2555**	0.0971
7	G							1.0000	1.0279**	0.5303**	0.5646**	1.2395**	0.8578**	0.5980**	0.3285**	0.4066**
	P							1.0000	0.7487**	0.2937**	0.4631**	0.5541**	0.0857	0.3307**	0.2571**	0.2381**
8	G								1.0000	0.4579**	0.5778**	0.8690**	-.1935**	0.3998**	0.5034**	0.5402**
	P								1.0000	0.4456**	0.5436**	0.6168**	-0.0197	0.3318**	0.3854**	0.3792**
9	G									1.0000	-.2765**	0.2373**	-.3201**	-0.1481	0.4469**	0.4662**
	P									1.0000	-.2106**	0.1489	-0.0359	0.1028	0.3354**	0.4103**
10	G										1.0000	0.9042**	0.0770	0.2878**	0.2067*	0.1893*
	P										1.0000	0.6309**	-0.0384	0.2594**	0.2029**	0.0670
11	G											1.0000	-0.1176	0.6487*	0.5170**	0.3298**
	P											1.0000	0.1610*	0.0674	0.4331**	0.1683*
12	G												1.0000	-0.0052	0.3733**	0.0195
	P												1.0000	-0.0097	0.1330	0.1610*
13	G													1.0000	0.2507**	0.0901
	P													1.0000	0.1789*	0.0674
14	G														1.0000	0.5230**
	P														1.0000	0.4331**
15	G															1.0000
	P															1.0000

Path Coefficient Analysis

Path coefficient analysis is important tool for partitioning the correlation coefficients into direct and indirect effects of independent variables on a dependent variable. Phenotypic path coefficient analysis is presented in Table 2, which revealed that positive and maximum direct effect on bulb yield was exerted by number of cloves per bulb followed by bulb weight, total soluble solids, days to maturity, pseudo stem height, number of leaves per plant, leaf width at middle portion, plant height and clove weight. These characters turned out to be major components of bulb yield. Maximum direct effect of number of cloves per bulb, bulb weight and plant height was reported by Sharma *et al*. (2016) [7] and Kumar *et al*. (2017) [5]. Direct effect of clove weight and

number of leaves per plant on bulb yield was noted by Kumar *et al*. (2015) [6] and Vinukonda *et al*. (2016) [5]. Considerable effect of pseudo stem height on bulb yield was reported by Singh *et al*. (2013) [11]. The characters number of cloves per bulb, bulb weight, days to maturity, pseudo stem height, plant height and number of leaves per plant also had positive and highly significant correlation with bulb yield. Hence these characters should be given much emphasis during selection for improvement of bulb yield in garlic.

Maximum and negative direct effects were exerted on bulb yield by bulb polar diameter followed by neck thickness, bulb equatorial diameter, leaf length and clove length. However, all the above characters had positive association with bulb yield because of the cumulative minor positive indirect effects *via* rest of the characters. Negative direct effects of bulb polar diameter and leaf length were reported by Prajapati *et al.* (2016) [7]. The negative direct effect of bulb polar diameter and clove length was nullified by considerable and positive indirect effects of these characters *via* bulb weight.

Plant height exerted considerable and positive indirect effect *via* pseudo stem height indicated that appreciable indirect effect on bulb yield was possible through this character, Considerable amount of indirect effects *via* bulb weight was observed for the characters bulb polar diameter, number of cloves per bulb, clove weight, clove length and pseudo stem height indicated indirect selection of these characters through bulb weight would help in improvement of bulb yield.

Table 2: Phenotypic path coefficient analysis showing direct (diagonal and bold) and indirect effects of different characters on bulb yield in garlic

Characters	Plant height (cm)	Number of leaves per plant	Leaf Length (cm)	Leaf width at middle portion (cm)	Days to maturity (days)	Bulb equatorial diameter (cm)	Bulb polar diameter (cm)	Bulb weight (g)	Number of cloves per bulb	Clove weight (g)	Clove length (cm)	Total soluble solids (%)	Neck thickness (cm)	Pseudo stem height (cm)	Phenotypic correlation with yield
Plant height (cm)	0.0452	-0.0099	-0.0170	0.0011	-0.0175	-0.0047	-0.0325	0.0511	0.0709	0.0067	-0.0031	0.0250	-0.0144	0.1131	0.2140**
Number of leaves per plant	-0.0022	0.2019	0.0002	0.0093	0.0706	-0.0031	-0.0781	0.0620	0.0541	0.0032	-0.0037	-0.0550	0.0003	0.0426	0.3021**
Leaf length (cm)	0.0284	-0.0012	-0.0271	0.0025	0.0049	-0.0050	-0.0438	0.0299	0.0493	0.0041	-0.0024	0.0210	-0.0119	0.0552	0.1039
Leaf width at middle portion (cm)	0.0008	0.0309	-0.0011	0.0609	0.0590	-0.0075	-0.1237	0.1024	0.0050	0.0134	-0.0070	-0.0031	-0.0217	0.0180	0.1263
Days to maturity (days)	-0.0035	0.0640	-0.0006	0.0161	0.2228	-0.0039	-0.1065	0.0794	0.0209	0.0041	-0.0036	-0.0090	-0.0096	0.0252	0.2958**
Bulb equatorial diameter (cm)	0.0047	0.0137	-0.0029	0.0099	0.0189	-0.0458	-0.0668	0.0760	0.0629	0.0046	-0.0025	-0.0239	-0.0051	0.0534	0.0971
Bulb polar diameter (cm)	0.0056	0.0602	-0.0045	0.0288	0.0907	-0.0117	-0.2619	0.1962	0.0800	0.0172	-0.0141	0.0191	-0.0201	0.0526	0.2381**
Bulb weight (g)	0.0088	0.0478	-0.0031	0.0238	0.0675	-0.0133	-0.1960	0.2621	0.1210	0.0202	-0.0156	-0.0044	-0.0200	0.0804	0.3792**
Number of cloves per bulb	0.0118	0.0403	-0.0049	0.0011	0.0171	-0.0106	-0.0771	0.1168	0.2714	-0.0078	-0.0038	-0.0080	-0.0060	0.0700	0.4103**
Clove weight (g)	0.0081	0.0173	-0.0030	0.0219	0.0248	-0.0056	-0.1209	0.1425	-0.0572	0.0372	-0.0160	-0.0086	-0.0160	0.0425	0.0670
Clove length (cm)	0.0055	0.0296	-0.0025	0.0168	0.0318	-0.0046	-0.1454	0.1618	0.0403	0.0234	-0.0253	0.0025	-0.0138	0.0482	0.1683*
Total soluble solids (%)	0.0050	-0.0497	-0.0025	-0.0008	-0.0090	0.0049	-0.0224	-0.0052	-0.0097	-0.0014	-0.0003	0.2236	0.0008	0.0277	0.1610*
Neck thickness (cm)	0.0107	-0.0011	-0.0053	0.0217	0.0352	-0.0039	-0.0865	0.0862	0.0266	0.0098	-0.0058	-0.0029	-0.0608	0.0435	0.0674
Pseudo stem height (cm)	0.0245	0.0412	-0.0071	0.0052	0.0269	-0.0117	-0.0673	0.1010	0.0910	0.0075	-0.0058	0.0297	-0.0108	0.2088	0.4331**

Conclusion

It can be revealed from the above studies that the characters bulb polar diameter, bulb weight, number of cloves per bulb, clove weight, clove length and pseudo stem height may be of merit value while making selection for desirable genotypes since these traits had positive and significant association with bulb yield as well as the contributed considerably towards bulb yield by directly and indirectly.

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