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Character association and path coefficient analysis of yield and its contributing traits in garlic (*Allium sativum* L.)

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Abstract

Sixty genotypes including four check varieties (G-50, G-41, G-282 and Punjab Garlic) of garlic (*Allium sativum* L.) were assessed to work out the association of different yield traits, direct and indirect effects of their various attributes on yield per plant. The number of cloves per bulb exhibited highly significant and positive phenotypic correlation with bulb yield per plant whereas, highly significant negatively correlated with weight of clove. Total soluble solids exhibited highly significant and positive correlation with bulb yield per plant. The highest direct positive effect towards bulb yield per plant was observed for number of cloves per bulb, weight of clove and total soluble solids, at phenotypic level. However length of leaf, diameter of bulb, length of clove and diameter of clove had exerted negative direct effect on bulb yield per plant. The number of cloves per bulb *via* length of bulb, number of cloves per bulb *via* length of leaf and weight of clove *via* length of clove, had exerted maximum positive indirect effect on bulb yield per plant.

Keywords: Garlic (*Allium sativum* L.), Character association, path coefficient analysis and bulb yield

Introduction

Garlic (*Allium sativum* L.) is classified under the class monocotyledone $2n=2x=16$, and belongs to the section Porrum of the family Alliaceae. It is known as *Lahsun* in Hindi, is the second important bulb crop after onion grown in India. It is also important foreign exchange earner and used as spices & condiments. Garlic is rich in protein, phosphorus, potassium, calcium, carbohydrates and also considered as "Nectar of Life" in Ayurveda.

Central Asia is the primary centre of origin of garlic followed by Mediterranean region. Garlic is cultivated from long ancient times. Its wild ancestor *Allium longicuspis* regal is native to Central Asia. It is well known in pre-dynastic cemeteries in Egypt before 3,000 B.C. It was reached to China and India and grown widely since a long times and carried out to Western hemisphere by Spanish, Portuguese and French and widely grown & used in Mediterranean climates. The major garlic growing countries are France, Spain, U.S.A. Brazil and Egypt. Asia contributes major parts in total world production. It was used in England as early as first half of the 16th Century. It is frost resistant vegetable crop grown throughout the India. China is the leading country in area & production of garlic followed by India.

In India, the total area covered under garlic is about 0.26 Million hectare with production of 1.42 Million tonnes and their productivity is 5.43 tonnes per hectare of bulb. (Anonymous, 2015) [1]. Madhya Pradesh is the leading state in garlic production, its share, 0.06 Million hectare area with 0.27 Million tonnes production. The important garlic growing states are Gujarat, Maharashtra, Uttar Pradesh, Andhra Pradesh, Orissa, Tamil Nadu and Rajasthan.

Garlic has higher nutritive value than other bulb crops. A colourless, odourless, water-soluble amino acid known as *Alliin* is present in uninjured garlic cloves. On injury of the cells, an enzyme, allinase comes in contact with alliin and causes its breakdown into a sulphur containing product allicin (Diallylthiosulfinate). Allicin is the antibacterial substance of garlic and has the typical odour of fresh garlic. It is unstable and breaks down into the strong smelling constituents of garlic oil. The alliin of *Allium sativum* contains an allyl radical from which the pungent Diallyl di-sulphide, is derived, which is responsible for pungency in garlic. Garlic contains 0.1-0.4% essential oil. The chief constituents of the oil are diallyldi-sulphide (60%), diallyltrisulphide (20%), allyl-propyl disulphide (6%) and small quantity of diethyl disulphide.

Garlic has good medicinal properties. It is carminative, gastric stimulants, helps in the digestion of food & absorption of nutrient from it.

The inhalation of garlic oil or garlic juice has generally been recommended in case of pulmonary tuberculosis, rheumatism, sterility, impotency, cough and red eyes.

The garlic extracts has nematicidal, bactericidal and fungicidal properties. The antioxidant potential of garlic is one of the great interest in connection with the anti-atherosclerotic & cardio protective effects observed epidemiologically and clinically. A formulation containing 1% garlic extract gave protection to persons against mosquitoes & black fly.

Garlic plants have flat, grayish-green leaves, which grow 1-2 feet. It is sexually sterile plants, the plants send up slender stalks, which produce round white bulb. Single bulb is composed of many sections called as cloves, which are held together by parchment like covering. It was observed that the seed stalk bears a terminal inflorescence which in turn bears bulbils instead of flowers. The shoot becomes flat and finally aborts after the development of bulbils in the inflorescence.

Garlic is vegetatively propagated by cloves, and those cultivars that still bolt, by inflorescence bulbils. Some modern cultivars produces flowers mixed with bulbils, but the flowers never set seeds. Garlic thus presents an interesting problems as to the origin of many cultivars, differing in maturity, bulb size, clove size and number, scale colour, bolting and presence and absence of flowers, it is not known how much variation due to bud mutation has arises after garlic became vegetatively propagated.

Materials and methods

The study was designed to work out the status of association of different yield traits and direct and indirect effects of these different traits on yield per plant among 60 garlic (*Allium sativum* L.) genotypes at field experiment under present investigation was conducted during *Rabi* 2014-15 at the Main Experiment Station, Vegetable Science, N. D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) India. The experimental materials of studies comprised of 60 garlic (*Allium sativum* L.) genotypes including four check varieties *viz.*, G-50, G-41, G-282 and Punjab Garlic. The experiment was laid out in Augmented Block Design, with plot size of 2.0×0.60 m² with distance of 30 cm row to row and 10 cm plant to plant. Observation were recorded on plant height (cm), number of leaves per plant, length of leaf (cm), width of leaf (cm), neck thickness of bulb (cm), diameter of bulb (cm), length of bulb (cm), bulb yield per plant (g), number of cloves per bulb, length of clove (cm), weight of clove (g), diameter of clove (cm) and total soluble solids (%). Standard statistical techniques such as correlation between different characters and path coefficient analysis. The correlations between different characters at genotypic (g) and phenotypic (p) levels were worked out between characters as suggested by Searle (1961)^[5]. Path coefficient analysis was done according to the formula given by Dewey and Lu (1959)^[3].

Results and discussions

The phenotypic and genotypic correlations coefficients were worked out to measure the association among the thirteen characters under study. The estimates of these correlation coefficients are presented in table-1 and 2. In general the estimates of genotypic correlation coefficients between different characters showed close parallelism in direction with their corresponding phenotypic correlation coefficients. The genotypic correlations were higher in magnitude than the corresponding correlation at phenotypic level table-1 and 2.

The plant height exhibited highly significant and positive phenotypic correlation with number of leaves per plant (0.373), length of leaf (0.357), length of bulb (0.372), where as significant phenotypic correlation with number of cloves per bulb (0.210), while highly significant and negative correlation with width of leaf (-0.274) and diameter of clove (-0.274). The number of leaves per plant showed positive and highly significant association with length of leaf (0.366), width of leaf (0.321). The length of leaf exhibited highly significant and positive phenotypic correlation with significant length of bulb (0.264) and number of cloves per bulb (0.210). The width of leaf showed highly significant and negative phenotypic correlation with diameter of bulb, length of bulb, neck thickness of bulb, number of cloves per bulb and diameter of clove whereas positive correlation with highly significant length of clove (0.300). The length of bulb showed highly significant and positive phenotypic correlation with number of cloves per bulb (0.289) and bulb yield per plant (0.413). The neck thickness of bulb showed negative and significant correlation with length of clove (-0.252). The number of cloves per bulb exhibited significant and positive phenotypic correlation with highly significant bulb yield per plant (0.719) whereas, negatively correlated with highly significant weight of clove (-0.418). The diameter of clove showed highly significant and negative phenotypic correlation. Total soluble solids exhibited highly significant and positive correlation with bulb yield per plant (0.282). Similar findings have been also reported by Tsega *et al.* (2010)^[10], Panse *et al.* (2013)^[4] and Tiwari *et al.* (2014)^[9]. While, plant height with width of leaf and diameter of clove, width of leaf with diameter of bulb, length of bulb, neck thickness of bulb, number of cloves per bulb and diameter of clove, number of cloves per bulb with weight of clove, exhibited highly significant and negative association. However, plant height had significant and positive correlation with number of cloves per bulb, length of leaf with length of bulb. Similar findings have been also reported by Sharma *et al.* (1990)^[7], Singh (1984)^[8].

Path coefficient analysis was carried out using phenotypic and genotypic correlation coefficients between twelve characters to find out direct and indirect effects with dependent character *i.e* bulb yield per plant (g) are presented in table-3 and 4, respectively. The highest direct positive effect towards bulb yield per plant (g) was observed for number of cloves per bulb (0.896), weight of clove (0.490), total soluble solids (0.152), length of bulb (0.123), neck thickness of bulb (0.09), width of leaf (0.08) and number of leaves per plant (0.02) at phenotypic level. Similar results have been reported by Barman *et al.* (1998)^[2], Yadav *et al.* (2007)^[11] and Tiwari *et al.* (2014)^[9]. However length of leaf (-0.051), diameter of bulb (-0.020), length of clove (-0.015), diameter of clove (-0.010) and plant height (-0.008) had exerted negative direct effect on bulb yield per plant. The number of cloves per bulb *via* length of bulb (0.259), number of cloves per bulb *via* length of leaf (0.188), weight of clove *via* length of clove (0.077), weight of clove *via* width of leaf (0.062), length of bulb *via* plant height (0.045), length of bulb *via* number of cloves per bulb (0.035) and width of leaf *via* number of leaves per plant (0.025) had exerted maximum positive indirect effect on bulb yield per plant. Similar results have been reported by Selvaraj *et al.* (1997)^[6]. However, length of leaf *via* diameter of clove (-0.006), length of leaf *via* TSS (-0.004), length of clove *via* neck thickness of bulb (-0.003), diameter of clove *via* plant height (-0.002) had exerted negative indirect effects on bulb yield per plant.

Table 1: Phenotypic (P) correlation coefficients between 13 characters in garlic germplasm

Characters	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Diameter of Bulb (cm)	Length of Bulb (cm)	Neck Thickness of Bulb (cm)	Number of cloves per Bulb	Length of Clove (cm)	Weight of Clove (g)	Diameter of Clove (cm)	T.S.S. (%)	Yield per plant (g)
Plant height (cm)	0.373**	0.357**	-0.274**	0.054	0.372**	0.090	0.210*	-0.069	-0.042	-0.274**	0.022	0.187
Number of leaves per plant		0.366**	0.321**	-0.033	0.175	-0.119	0.101	0.176	-0.050	-0.195	0.093	0.116
Length of leaf (cm)			-0.014	0.044	0.264*	0.010	0.210*	-0.057	-0.006	-0.116	-0.084	0.159
Width of leaf (cm)				-0.107	-0.017	-0.074	-0.040	0.300**	0.128	-0.085	0.077	0.117
Diameter of Bulb (cm)					0.029	0.130	-0.098	-0.053	-0.000	-0.044	0.133	-0.083
Length of Bulb (cm)						-0.136	0.289**	-0.002	0.060	-0.189	0.179	0.413**
Neck Thickness of Bulb (cm)							-0.046	-0.252*	0.108	0.020	0.139	0.098
Number of cloves per Bulb								-0.190	-0.418**	0.010	0.031	0.719**
Length of Clove (cm)									0.158	0.048	0.099	-0.085
Weight of Clove (g)										-0.048	0.116	0.158
Diameter of Clove (cm)											-0.157	-0.073
T.S.S. (%)												0.282**

*, ** Significant at 5% and 1% probability level, respectively

Table 2: Genotypic (G) correlation coefficients between 13 characters in garlic germplasm.

Characters	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Diameter of Bulb (cm)	Length of Bulb (cm)	Neck Thickness of Bulb (cm)	Number of cloves per Bulb	Length of Clove (cm)	Weight of Clove (g)	Diameter of Clove (cm)	T.S.S. (%)	Yield per plant (g)
Plant height (cm)	0.385	0.383	-0.284	0.040	0.384	0.103	0.211	-0.081	-0.053	-0.286	0.017	0.194
Number of leaves per plant		0.383	0.326	-0.039	0.167	-0.120	0.108	0.180	-0.052	-0.196	0.106	0.133
Length of leaf (cm)			-0.015	0.051	0.282	0.011	0.216	-0.055	-0.009	-0.127	-0.075	0.171
Width of leaf (cm)				-0.108	-0.017	-0.076	-0.039	0.303	0.127	-0.084	0.077	0.121
Diameter of Bulb (cm)					0.031	0.131	-0.104	-0.057	-0.003	-0.044	0.147	-0.084
Length of Bulb (cm)						-0.138	0.294	-0.009	0.062	-0.192	0.216	0.430
Neck Thickness of Bulb (cm)							-0.043	-0.255	0.110	0.020	0.160	0.104
Number of cloves per Bulb								-0.192	-0.422	0.011	0.033	0.729
Length of Clove (cm)									0.162	0.050	0.114	-0.091
Weight of Clove (g)										-0.048	0.113	0.160
Diameter of Clove (cm)											-0.157	-0.072
T.S.S. (%)												0.178

*, ** Significant at 5% and 1% probability level, respectively

Table 3: Direct and indirect effects of 12 characters on bulb yield per plant in garlic at phenotypic level.

Characters	Plant height (cm)	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Diameter of Bulb (cm)	Length of Bulb (cm)	Neck Thickness of Bulb (cm)	Number of cloves per Bulb	Length of Clove (cm)	Weight of Clove (g)	Diameter of Clove (cm)	T.S.S. (%)	Yield per plant (g)
Plant height (cm)	-0.008	-0.003	-0.003	0.002	-0.000	-0.003	-0.000	-0.001	0.000	0.000	0.002	-0.000	0.187
Number of leaves per plant	0.007	0.020	0.007	0.006	-0.000	0.003	-0.002	0.002	0.003	-0.001	-0.004	0.001	0.116
Length of leaf (cm)	-0.018	-0.018	-0.051	0.000	-0.002	-0.013	-0.000	-0.010	0.003	0.000	0.006	0.004	0.159
Width of leaf (cm)	-0.022	0.025	-0.001	0.080	-0.008	-0.001	-0.006	-0.003	0.024	0.010	-0.006	0.006	0.117
Diameter of Bulb (cm)	-0.001	0.000	-0.000	0.002	-0.020	-0.000	-0.002	0.002	0.001	0.000	0.000	-0.002	-0.083
Length of Bulb (cm)	0.045	0.021	0.032	-0.002	0.003	0.123	-0.016	0.035	-0.000	0.007	-0.023	0.022	0.413
Neck Thickness of Bulb (cm)	0.008	-0.010	0.001	-0.006	0.011	-0.012	0.091	-0.004	-0.023	0.009	0.001	0.012	0.098
Number of cloves per Bulb	0.188	0.091	0.188	-0.036	-0.088	0.259	-0.041	0.896	-0.170	-0.375	0.009	0.028	0.719
Length of Clove (cm)	0.001	-0.002	0.000	-0.004	0.000	0.000	0.003	0.003	-0.015	-0.002	-0.000	-0.001	-0.085
Weight of Clove (g)	-0.020	-0.024	-0.003	0.062	-0.000	0.029	0.053	-0.205	0.077	0.490	-0.023	0.056	0.158
Diameter of Clove (cm)	0.002	0.002	0.001	0.000	0.000	0.001	-0.000	-0.000	-0.000	0.000	-0.010	0.001	-0.073
T.S.S. (%)	0.003	0.014	-0.012	0.011	0.020	0.027	0.021	0.004	0.015	0.017	-0.024	0.152	0.282

Residual effect = 0.4107

Table 4: Direct and indirect effects of 12 characters on bulb yield per plant in garlic at genotypic level.

Characters	Plant height (cm)	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Diameter of Bulb (cm)	Length of Bulb (cm)	Neck Thickness of Bulb (cm)	Number of cloves per Bulb	Length of Clove (cm)	Weight of Clove (g)	Diameter of Clove (cm)	T.S.S. (%)	Yield per plant (g)
Plant height (cm)	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000	0.194
Number of leaves per plant	0.013	0.034	0.013	0.011	-0.001	0.005	-0.004	0.003	0.006	-0.001	-0.006	0.003	0.133
Length of leaf (cm)	-0.023	-0.023	-0.060	0.000	-0.003	-0.017	-0.000	-0.013	0.003	0.000	0.007	0.004	0.171
Width of leaf (cm)	-0.024	0.027	-0.001	0.085	-0.009	-0.001	-0.006	-0.003	0.025	0.010	-0.007	0.006	0.121
Diameter of Bulb (cm)	-0.000	0.000	-0.000	0.001	-0.011	-0.000	-0.001	0.001	0.000	0.000	0.000	-0.001	-0.084
Length of Bulb (cm)	0.047	0.020	0.034	-0.002	0.003	0.122	-0.017	0.036	-0.001	0.007	-0.023	0.026	0.430
Neck Thickness of Bulb (cm)	0.009	-0.010	0.001	-0.006	0.011	0.012	0.089	-0.003	-0.022	0.009	0.001	0.014	0.104
Number of cloves per Bulb	0.193	0.099	0.197	-0.036	-0.095	0.269	-0.040	0.913	-0.175	-0.386	0.010	0.030	0.729
Length of Clove (cm)	0.002	-0.004	0.001	-0.007	0.001	0.000	0.006	0.004	-0.025	-0.004	-0.001	-0.002	-0.091
Weight of Clove (g)	-0.027	-0.026	-0.004	0.064	-0.001	0.031	0.056	-0.214	0.082	0.507	-0.024	0.057	0.160
Diameter of Clove (cm)	0.002	0.001	0.000	0.000	0.000	0.001	-0.000	-0.000	-0.000	0.000	-0.007	0.001	-0.072
T.S.S. (%)	0.002	0.014	-0.010	0.010	0.020	0.029	0.022	0.004	0.015	0.015	-0.021	0.137	0.278

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