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Correlation and Path Analysis for Yield and Yield Attributing Traits in Garlic (*Allium sativum* L.)

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ABSTRACT

In general, the estimates of genotypic correlation were higher than the corresponding phenotypic correlation coefficient. It may result from the modifying effect of environment on the association of characters at genotypic level. The character bulb yield had highly significant positive correlation with characters like bulb weight, weight of 10 uniform cloves, fresh weight of bulb, dry weight of bulb, neck thickness, and vitamin C. Path coefficient analysis revealed that the characters like bulb weight, fresh weight of leaves, dry weight of bulb, and circumference of bulb, neck thickness, and volume of bulb, and vitamin C had high direct effect on bulb yield. These above characters also had positive indirect effect with each other. Fresh weight of leaves, dry weight of bulb, neck thickness and circumference of bulb, volume of bulb, and vitamin C showed high and positive indirect effect towards bulb yield through bulb weight.

Key words: *Allium sativum* L., Correlation, Path analysis, Yield, Traits

Garlic (*Allium sativum* L.) is an important spice and condiment crop grown throughout the country as well as world. It is one of the most important bulb vegetable crops which have been used since ancient for its culinary, medicinal and health benefits [1]. Garlic is the second most important bulb crop after onion. It is an important spice crop belonging to family *Alliaceae* and botanically known as (*Allium sativum* L.). Growth of garlic mainly depends on the time of planting as the vegetative growth is stimulated under a short photoperiod and low temperature and bulb production is enhanced by a long photoperiod and high temperature [2]. The economic yield is obtained from its underground bulb, which is consisted of bulblets, popularly called as cloves. Garlic is used in flavoring foods, preparing chutneys, pickles, curry powder, tomato ketchup etc. It contains protein (6.3%), phosphorus (0.31%), potash (0.40%), calcium (0.03%), magnesium (0.025%), carbohydrates (29%) and a colourless as well as odourless water soluble amino acid called allicin. On crushing the blub clove, an enzyme *allinase* acts upon *allicin* and breaks down to produce *allicin*. Garlic contains volatile oil known as *diallel - disulphide* which is the major flavouring component in garlic. Beneficial use of garlic extract has been found against many fungi and bacteria [3]. Besides the nutritive value of garlic and its use in various forms, it is included in Indian system of medicines (Ayurvedic, Unani and Siddha) as carminative and gastric stimulant to help indigestion and absorption of food. Garlic is a scapigerous foeti perennial medicinal herb with underground compound bulbs covered by outer white thin scales with simple smooth round stem surrounded by the bottom by tublar leaf sheath [4]. Allicin present in aqueous extract of garlic reduce blood cholesterol concentration in human blood [5]. Garlic oil or its juice is recommended to inhale in cases of pulmonary tuberculosis, rheumatism, sterility, impotency, cough and redness of eyes [6]. India ranks second after China in area (171.45 thousand hectare) and second in production (923.250 thousand tonnes) of garlic with an average productivity of 4.38 tonnes per hectare [7]. The major garlic producing states of India are Maharashtra, Madhya Pradesh, Orissa, Rajasthan, Karnataka, Uttar Pradesh and Gujarat. India is one of the most garlic exporting countries in the world. The export was 13008.78 tonnes (worth Rs. 1962.66 lakh) in 2019. Correlation estimates between yield and its components are useful in developing suitable selection criteria for selecting desired plant type or developing high yield varieties. Path analysis is helpful in choosing the character(s) that have direct or simultaneous improvement of component characters that contribute towards yield.

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MATERIALS AND METHODS

The present investigation was carried out at Horticulture research farm of Department of Horticulture, Babasaheb Bhimrao Ambedkar University (A Central University), Vidya-Vihar, Lucknow, Uttar Pradesh during winter season. The experimental material comprised of 25 garlic germplasm. The twenty-five genotypes of garlic used for the present investigation were collected from the different parts of India. The experiment was laid down in a randomized block design with three replications. The row to row spacing 15 cm and plant to plant 10 cm in double row of 5 meter length of each genotype were planted. All the standard package of practices and plant protection measures were timely adopted to raise the crop successfully. The observations were recorded on plant height (cm), number of leaves per plant, bulb weight (g), number of cloves per bulb, weight of ten uniform cloves (g), bulb yield (q/h^{-1}), fresh weight of bulbs (g), dry weight of bulb (g), fresh weight of leaves (g), dry weight of leaves (g), neck thickness (cm), circumference of bulb (cm), volume of bulb, total soluble solids (%) (°Brix) and Vitamin 'C' (mg/100g). Ten plants were taken at random in each plot for recording the data of various traits and tagged for identification. Correlation and path coefficient analysis were calculated as per formulae suggested by Dewey and Lu [8], respectively.

RESULTS AND DISCUSSION

Correlation coefficient

Phenotypic and genotypic correlation coefficients among fifteen quantitative and qualitative characters are presented in (Table 1). The significant correlation coefficients at phenotypic level, all correlation coefficients were positive. For most of the characters, genotypic correlation coefficient was found to be higher in magnitude than phenotypic correlation coefficient, indicating a strong inherent association among various characters. In general, the genotypic correlation coefficients were higher than the respective phenotypic correlations which might from the 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. Knowledge of relation between bulb yield and its components is essential and selection for one component may bring about a simultaneous change in the other [9]. Therefore, for a rational approach to improve bulb yield, it may be useful to collect information on character association. Bulb yield showed significant positive correlation with dry weight of bulb (r_p=0.405*, r_g=0.564), neck thickness (r_p=0.467*, r_g=0.489), sulphur content (r_p=0.611**, r_g=0.689), vitamin C (r_p=0.545**, r_g=0.616) and bulb weight (r_p=0.438*, r_g=0.616). Although it showed positive and non-significant correlation with plant height at 90 DAS, number of leaves per plant, dry weight of leaves, weight of 10 uniform cloves, fresh weight of bulb, circumference of bulb, volume of bulb and TSS. Plant height at 90 DAS showed significant positive correlation with fresh weight of leaves (r_p=0.538**), dry weight of leaves (r_p=0.481**), number of cloves per bulb (r_p=0.339*), weight of 10 uniform cloves (r_p=0.515**), fresh weight of bulb (r_p=0.568**), dry weight of bulb (r_p=0.626**), circumference of bulb (r_p=0.610**), volume of bulb (r_p=0.487**) and bulb weight (r_p=0.560**).

Table 1 Genotypic and phenotypic correlation coefficient for fifteen characters in garlic

Characters		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Plant height (cm)	G	1.000	0.068	0.5**	0.481**	0.399*	0.515**	0.568**	0.626**	0.217	0.610**	0.487*	0.103	0.161	0.560**	0.226
	P	1.000	0.099	0.623	0.598	0.409*	0.554	0.622	0.681	0.395	0.804	0.568	0.59	0.267	0.589	0.264
2. No. of leaves plant^{-1}	G		1.000	0.020	0.128	0.011	-0.188	-0.095	0.124	0.163	0.020	0.029	-0.190	0.062	0.040	0.136
	P		1.000	-0.156	0.293	0.125	-0.388	-0.144	0.281	-0.071	0.007	0.053	-0.481*	0.246	0.011	0.350
3. Fresh weight of leaf (g)	G			1.000	0.488**	0.451*	0.233	0.471*	0.174	0.147	0.361	0.278	-0.023	-0.029	0.377	-0.013
	P			1.000	0.859	0.594	0.217	0.565	0.328	0.299	0.449	0.399	0.125	-0.035	0.461	-0.058
4. Dry weight of leaf (g)	G				1.000	0.196	0.329	0.544**	0.557**	0.378	0.299	0.442*	0.225	0.173	0.507**	0.179
	P				1.000	0.239	0.524	0.717	0.677	0.644	0.563	0.571	0.204	0.419*	0.608	0.375
5. No. of cloves/bulb	G					1.000	-0.158	0.215	-0.001	-0.150	0.274	0.055	-0.271	-0.327	0.221	-0.294
	P					1.000	-0.175	0.262	-0.012	-0.248	0.402	0.079	-0.545	-0.547	0.250	-0.373
6. Weight tan uniform cloves (g)	G						1.000	0.573**	0.597**	0.376	0.459*	0.534**	0.331	0.450*	0.553**	0.379
	P						1.000	0.654	0.714	0.701	0.675	0.640	0.493	0.685	0.630	0443
7. Fresh weight of bulb (g)	G							1.000	0.552**	0.477*	0.544**	0.660**	0.206	0.252	0.840**	0.331
	P							1.000	0.647	0.871	0.776	0.835	0.328	0.672	0.966	0.416
8. Dry weight of bulb (g)	G								1.000	0.343	0.341	0.575**	0.301	0.374	0.554*	0.405*
	P								1.000	0.735	0.538	0.666	0.431	0.594	0.641	0.564
9. Neck thickness (cm)	G									1.000	0.246	0.259	0.207	0.479*	0.512*	0.467*
	P									1.000	0.894	0.706	0.593	0.494	0.950	0.489
10. Circumference of bulb (cm)	G										1.000	0.447**	0.036	0210	0.562*	0.300
	P										1.000	0.594	0.200	0.696	0.799	0.396
11. Volume of bulb (cc)	G											1.000	0.245	0.158	0.639*	0.188
	P												0.400	0.522	0.747	0.281
12. TSS (%)	G												1.000	0.307	0.148	0.257
	P													0.520	0.212	0.390
13. Vitamin C (mg/100g)	G													1.000	0.452*	0.545*
	P													1.000	0.682	0.648
14. Bulb weight (g)	G														1.000	0.438*
	P														1.000	0.616*
15. Bulb yield (q/ha)	G															1.000
	P															1.000

Fresh weight of leaves showed significant positive correlation with dry weight of leaves (r_p=0.488**), number of cloves per bulb (r_p=0.451*), fresh weight of bulb (r_p=0.471*). Dry weight of leaves had significant positive correlation with fresh weight of bulb (r_p=0.544**), dry weight of bulb (r_p=0.557**), volume of bulb (r_p=0.442*), sulphur content (r_p=0.438*), and bulb weight (r_p=0.507**). Weight of 10 uniform cloves had significant positive correlation with fresh weight of bulb (r_p=0.573**), dry weight of bulb (r_p=0.597**), circumference of bulb (r_p=0.459*), volume of bulb (r_p=0.534**), vitamin C (r_p=0.450*) and bulb weight (r_p=0.553**). Fresh weight of bulb has significant positive correlation with dry weight of bulb (r_p=0.552**), neck thickness (r_p=0.477*), circumference of bulb (r_p=0.544), volume of bulb (r_p=0.660**) and bulb weight (r_p=0.840**). Dry weight of bulb has significant positive correlation with volume of bulb (rp=0.575**), Sulphur content (rp=0.531**) and bulb weight (rp=0.554**). Neck thickness has significant positive correlation with sulphur content (r_p=0.598**), vitamin C (r_p=0.479*) and bulb weight (r_p=0.512**). Circumference of bulb has significance positive correlation with volume of bulb (r_p=0.447**) and bulb weight (r_p=0.562**). Volume of bulb has significant positive correlation with bulb weight (r_p=0.639**). Sulphur content showed significant positive correlation with vitamin C (r_p=0.577**) and bulb weight (r_p=0.468*). Vitamin C has significant positive correlation with bulb weight (r_p=0.452*). The correlation among number of leaves per plant, TSS, number of cloves per bulb and number of leaves per plant and their correlation with other characters were found to be non-significant. These observations are in accordance to [10-13].

Table 2 Phenotypic (P) path coefficients of various characters on bulb yield in garlic

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Correlation with bulb yield
1	**0.053**	0.006	0.090	-0.133	-0.133	-0.010	0.005	0.060	-0.004	0.112	-0.106	0.015	-0.002	0.174	0.226
2	0.004	**0.082**	0.003	-0.035	-0.004	0.004	-0.001	0.012	-0.003	0.004	-0.006	-0.027	-0.001	0.012	0.136
3	0.029	0.002	**0.168**	-0.135	-0.150	-0.004	0.004	0.017	-0.002	0.066	-0.061	-0.003	0.000	0.117	-0.013
4	0.026	0.011	0.082	**-0.276**	-0.065	-0.006	0.004	0.054	-0.006	0.055	-0.096	0.032	-0.002	0.157	0.179
5	0.021	0.001	0.076	-0.054	**-0.333**	0.003	0.002	0.000	0.002	0.05	-0.012	-0.039	0.004	0.069	-0.294
6	0.028	-0.015	0.039	-0.091	0.053	**-0.019**	0.005	0.057	-0.006	0.084	-0.116	0.047	-0.006	0.172	0.379
7	0.030	-0.008	0.079	-0.150	-0.072	-0.011	**0.008**	0.053	-0.008	0.099	-0.144	0.029	-0.003	0.261	0.331
8	0.033	0.010	0.029	-0.154	0.000	-0.011	0.004	**0.096**	-0.006	0.062	-0.125	0.043	-0.005	0.172	0.405*
9	0.012	0.013	0.025	-0.104	0.050	-0.007	0.004	0.033	**-0.017**	0.045	-0.056	0.029	-0.006	0.159	0.467*
10	0.033	0.002	0.061	-0.083	-0.091	-0.009	0.004	0.033	-0.004	**0.183**	-0.097	0.005	-0.003	0.174	0.300
11	0.026	0.002	0.047	-0.122	-0.018	-0.010	0.005	0.055	-0.004	0.082	**-0.218**	0.035	-0.002	0.198	0.188
12	0.006	-0.016	-0.004	-0.062	0.090	-0.006	0.002	0.029	-0.003	0.007	-0.053	**0.143**	-0.004	0.046	0.257
13	0.009	0.005	-0.005	-0.048	0.109	-0.008	0.002	0.036	-0.008	0.038	-0.034	0.044	**-0.013**	0.140	0.545**
14	0.030	0.003	0.063	-0.140	-0.074	-0.010	0.007	0.053	-0.009	0.103	-0.139	0.021	-0.006	**0.310**	0.438*

1. Plant height at 90 days after sowing (cm); 2. No. of leaves per plant; 3. Fresh weight of leaves (g); 4. Dry weight of leaves (g); 5. No. of cloves per bulb; 6. Weight of 10 uniform cloves (g); 7. Fresh weight of bulb (g); 8. Dry weight of bulb (g); 9. Neck thickness (cm); 10. Circumference of bulb (cm); 11. Volume of bulb (cc); 12. TSS (%); 13. Vitamin C (mg/100g); 14. Bulb weight (g)

Path coefficient analysis

Path coefficient analysis was carried out by taking bulb yield as dependent variable to partition the correlation coefficients into direct and indirect effects in order to determine the contribution of different characters towards the bulb yield are presented in (Table 2). Direct and indirect effects of various characters on bulb yield indicated that there is 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. The results of path coefficient analysis indicated that at the phenotypic level among the various characters studied had the highest positive direct effect on the bulb yield (0.438) followed by bulb weight (0.310), circumference of bulb (0.183), fresh weight of leaves (0.168), TSS (0.143), dry weight of bulb (0.096), number of leaves per plant (0.082), plant height at 90 DAS (0.053) and fresh weight of bulb (0.008), whereas number of cloves per bulb (-0.333), dry weight of leaves (-0.276), volume of bulb (-0.218), weight of 10 uniform cloves (-0.019), neck thickness (-0.017) and vitamin C (-0.013) had negative direct effect. The residual effect at phenotypic level was 0.430 which is moderate in magnitude indicating that the characters included in the study might explain major portion of contribution towards bulb yield. These results are similar with the findings of [14-17].

CONCLUSION

Thus, on the basis of present study it may be concluded that the characters like bulb weight, fresh weight of leaves, dry weight of bulb, circumference of bulb, neck thickness, volume of bulb, Sulphur content and vitamin C may be of merit value when making selection for desirable genotypes.

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