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CHARACTER ASSOCIATION AND PATH ANALYSIS IN GARLIC (*ALLIUM SPP.*) GERMPLASM UNDER SUB TROPICAL ENVIRONMENT OF JAMMU

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ABSTRACT
Genetic variability of 41 genotypes of garlic collected from different agroclimatic zone of Jammu division was assessed for yield, quality and other agronomic characters. The analysis of variance revealed greater variability for all the traits studied except number of leaves/plant, leaf length, dry matter content, total soluble solids and equatorial diameter. High heritability coupled with high genetic advance as percent of mean was observed for plant height (69.23%), average weight of cloves (66.3%), yield/ hectare (54.00%), leaf length (36.04%), equatorial diameter (32.20%) and average weight of bulbs (74.8%) which lead to additive gene action and their expression and phenotypic selection for their amenability can be brought about. Average bulb weight showed positive and significant correlation with number of leaves/plant, leaf length, average weight of cloves, equatorial diameter, while it was negative and significantly correlated with total soluble solids. Positive direct effect on average weight of bulb was observed for average weight of 10 cloves/bulb (0.950), dry matter (0.575), equatorial diameter (0.419), leaf length (0.127) and plant height (0.222). Therefore it can be inferred from the present study that good scope for garlic improvement in this region is possible through positive selection pressure on suitable traits in desirable genotypes.

INTRODUCTION

Common garlic (*Allium sativum* L.), a diploid species (2n = 2x = 16) and great headed garlic (*Allium ampeloprasum* L.), a tetraploid species (2n = 2x = 32), regarded as one of the important bulb crops grown and used as a spice crop or condiment throughout India (Singh and Srivastava, 1999). Theyare cultivated extensively throughout subtropical plains to intermediate higher reaches of Jammu, covering an area of 530 ha with a production of 7070 MT and productivity of 13.33MT/ha (Anonymous, 2014). Districts of Jammu region showing preponderance of garlic cultivation are Jammu, Rajouri and its adjoining areas like Nowshera, Jaba-Anjana and Dudasanwala; Poonch district including Manjakot, Surankot, Mandi, Loran and Mendhar;whole of Kathua districtincluding parts of Bani and Basoli; Udhampur (Basht and Chenani) and Doda (Bhadarwah). Garlic displays considerable variability with respect to morphological features, yield, quality features as well as resistance to important insect pests and diseases. It also shows adaptation to wide range of soil types, temperatures, day length etc making its farming possible from tropics to temperate latitudes. It also showed greater climatic adaptability, some being heat tolerant and others being frost hardy (Maab and Klass, 1995). Lack of flowering in most of the cultivated clones and seed sterility in those that do flower have restricted the sexual breeding and genetic studies in garlic (Ipek *et al.,* 2003). It is assumed that the vast diversity that has been observed in cultivated garlic goes back to variation generated from sexual reproduction in the wild crop (Simon, 2001). Existence of this natural variation even in respect of the plant parts that is economically important suggests the possibility of improvement in garlic. Once quantitatively and qualitatively superior clones are identified, their maintenance through vegetative propagation is assured (Singh and Chand,2003).Given that the germplasm of *Allium spp.* is highly variable for morpho-physiologic traits (Avento *et al.*,1998 and Langerano *et al.*, 1995), clones could be identified on the basis of canopy structure and yield related traits (Zepeda,1997). It was therefore considered important to study genetic variability,character association pattern and direct indirect effect of the contributing characters on bulb yield under subtropical environment of Jammu.

MATERIALS AND METHODS

A collection of 41 garlic genotypes comprising of fourteen hexaploids (*Allium ampeloprasum* L) and twenty seven diploids (*Allium sativum* L), from different zones of Jammu division including four released varieties from NHRDF Karnal, Haryana were evaluated against two checks *i.e.*, AgrifoundParvati (G-313) and Yamuna Safed (G-50) for ten morphological, yield and quality traits (Table 1). All the recommended cultural practices were followed during the entire growth period of crop to raise a healthy crop. Chatha is located in the subtropical zone of Jammu and Kashmir at 32º40´ North latitude and 74º58´ East longitude having an elevation of 332 m above msl. Its climate is subtropical with hot dry summer, warm humid rainy season and cold winters. The maximum temperature goes up to 47°C during summer (May to June) and minimum temperature falls below 10°C during winter (December-January). The mean annual rainfall during 2012 was 27.2mm whereas it was 13.2mm during 2013 (Source: *Agro meteorological section, Division of Agronomy, SKUAST-Jammu*). The soil of the experimental area was near neutral in reaction (pH = 6.3) with medium in nitrogen and phosphorus concentration but low in potassium level. All the observations were recorded as per standard procedures from five randomly selected plants of each genotype in all the three replications and their mean were worked out for statistical analysis (Panse and Sukhatme, 1967). Plant height was measured from base of the plant to the upper leaf at 80 days after sowing. Leaf length of the 4th leaf was measured from leaf axil up to its tip and leaf width was measured from the middle of the 4th leaf with the help of graduated scale whereas pseudo-stem length was measured from the soil level to inner leaf lamina notch of the plants and diameter was recorded below leaf level of the plant with the help of vernier calliper. All the morphological observations were recorded as per the standard procedure recommended for the crop in the Proceedings of All India Network Research Project on Onion and Garlic, Directorate of Onion and Garlic Research, Pune (Mah.). The phenotypic and genotypic coefficient of variance were calculated according to formulae (Burton and De-Vane, 1953). Heritability (broad sense) and expected genetic advance was calculated as per Johnson *et al*. (1955). The characters showing significant correlation with yield were utilized to compute direct and indirect contribution (Dewey and Lu, 1959).

RESULTS AND DISCUSSION

Analysis of variance showed considerable amount of variability in all the genotypes of garlic among various traits like plant height, leaf length, pseudostem length, average weight of 10 cloves, equatorial diameter, average weight of bulb, yield/ha except total soluble solids, dry matter weight and number of leaves (Table 2) and thus can be initialized for improvement of quantitative attributes of the crop (Nagi *et al*., 2013).

Phenotypic variability

Allium sativum is considered a species complex, shows great immense variability (Kamenetsky, 2007). Although belonging to a same group, the collections showed clear distinguishable features in many respects *viz*., leaf shape, colour and orientation, bulb shape and colour, days to harvest etc. 9 genotypes were broad leaved (leaf width > 1.5cm) and spreading in orientation, 7 were narrow leaved (leaf width < 1.5cm) and erect including check Yamuna Safed (G-50), 13 were broad leaved and erect in orientation including check AgrifoundParvati(G-313), whereas 10 genotypes were broad leaved showing prostate orientation. On the basis of clove colour, broadly two categories: white and pink white emerged among the collections. 20 genotypes showed whitish cloves where as 21 genotypes including both the checks showed pink-white cloves of the bulbs. On bulb shape basis, 30 genotypes showed ovate bulbs whereas 11 genotypes showed broadly ovate shape of the bulbs. Regarding foliage

Table 1: List of garlic genotypes and their source of collection

S. No	Genotype(s)	Source	Ploidy level (2n) = 16,32	S. No	Genotype(s)	Source	Ploidy level (2n) = 16,32
1	SJG-11-01	Kanachak (Jammu, J&K)	Diploid	22	SJG-11-22	Surankote (Poonch, J&K)	Hexaploid
2	SJG-11-02	Kanachak (Jammu, J&K)	Diploid	23	SJG-11-23	Panjgran (Rajouri, J&K)	Hexaploid
3	SJG-11-03	Bhaderwah(Doda,J&K)	Diploid	24	SJG-11-24	Jaba-Anjana (Rajouri, J&K)	Diploid
4	SJG-11-04	Kathua, J&K	Diploid	25	SJG-11-25	Thanamandi (Rajouri, J&K)	Hexaploid
5	SJG-11-05	Kathua, J&K	Diploid	26	SJG-11-26	Lower Loren (Poonch, J&K)	Diploid
6	SJG-11-06	Chandak (Poonch, J&K)	Diploid	27	SJG-11-27	Surankote (Poonch, J&K)	Diploid
7	SJG-11-07	Rajouri, J&K	Hexaploid	28	SJG-11-28	Dudasanwala (Poonch, J&K)	Diploid
8	SJG-11-08	Nowshera (Rajouri, J&K)	Diploid	29	SJG-11-29	Rajouri, J&K	Diploid
9	SJG-11-09	Poonch, J&K	Hexaploid	30	SJG-11-30	Surankote (Poonch,J&K)	Hexaploid
10	SJG-11-10	Khaneter (Poonch, J&K)	Hexaploid	31	SJG-11-31	Dandidhar (Poonch,J&K)	Diploid
11	SJG-11-11	Surankote (Poonch, J&K)	Hexaploid	32	SJG-12-01	Karlah Selection-1 (Udhampur, J&K)	Hexaploid
12	SJG-11-12	Surankote (Poonch, J&K)	Diploid	33	SJG-12-02	Karlah Selection-2 (Udhampur, J&K)	Diploid
13	SJG-11-13	Poonch, J&K	Hexaploid	34	SJG-12-03	Marh, Jammu, J&K	Diploid
14	SJG-11-14	Poonch, J&K	Diploid	35	SJG-12-04	Marh, Jammu, J&K	Diploid
15	SJG-11-15	Manjakot (Rajouri, J&K)	Hexaploid	36	G-408	NHRDF, Karnal, Haryana	Diploid
16	SJG-11-16	Rajouri, J&K	Hexaploid	37	Yamuna Safed (G-282)	NHRDF, Karnal, Haryana	Diploid
17	SJG-11-17	Chandak (Poonch, J&K)	Diploid	38	Yamuna Safed (G-323)	NHRDF, Karnal, Haryana	Diploid
18	SJG-11-18	Mandi (Poonch, J&K)	Hexaploid	39	Yamuna Safed (G-1)	NHRDF, Karnal, Haryana	Diploid
19	SJG-11-19	Rajouri, J&K	Hexaploid	40	Yamuna Safed (G-50)*	NHRDF, Karnal, Haryana	Diploid
2021	SJG-11-20SJ G-11-21	Upper Loren (Poonch, J&K)Rajouri, J&K	Hexaploid Diploid	41	Agrifound Parvati (G-313)*	NHRDF, Karnal, Haryana	Diploid

Table 2: Mean performance of various morphological, yield and quality characters in garlic genotypes

S. No.	Genotype(s)	Average weight of 10 cloves (g)	Average weight of bulbs (g)	Bulbil formation	Bulb shape	Clove Colour	Days to harvest	Dry matter content (%)	Equatorial diameter (cm)
1	SJG - 11 – 01	13.26	26.23	Present	Ovate	White	190	44.6	3.63
2	SJG - 11 – 02	9.33	28.13	Present	Broadly-ovate	Pink-white	190	39	3.46
3	SJG - 11 – 03	15.56	27	Absent	Ovate	White	190	37.6	3.4
4	SJG - 11 – 04	16.16	30.3	Absent	Ovate	White	190	38.3	3.36
5	SJG - 11 – 05	19.7	28.3	Absent	Ovate	Pink-white	190	39	4.03
6	SJG - 11 – 06	9.8	18.73	Absent	Broadly-ovate	White	190	28.6	2.46
7	SJG - 11 – 07	22.83	25.6	Absent	Ovate	White	205	39.6	3.8
8	SJG - 11 – 08	20.96	29.13	Absent	Ovate	White	190	28	3.7
9	SJG - 11 – 09	19.4	30.9	Absent	Ovate	White	190	38.6	3.5
10	SJG - 11 – 10	23.5	43.4	Absent	Ovate	White	190	41	4.16
11	SJG - 11 – 11	15.96	21.63	Absent	Ovate	White	190	40.3	3.66
12	SJG - 11 – 12	17.63	27.3	Absent	Ovate	White	205	36	3.63
13	SJG - 11 – 13	13.13	22.83	Absent	Broadly-ovate	White	190	42.6	3.3
14	SJG - 11 – 14	16.66	16.3	Absent	Broadly-ovate	Pink-white	190	26	2.3
15	SJG - 11 – 15	17.5	17.16	Absent	Ovate	White	190	51	3.7
16	SJG - 11 – 16	7.8	8.56	Absent	Ovate	White	190	43.3	2.76
17	SJG - 11 – 17	8	9.3	Absent	Ovate	Pink-white	205	36.6	2.23
18	SJG - 11 – 18	9.9	17.96	Present	Ovate	Pink-white	190	27	2.86
19	SJG - 11 – 19	9.33	26.83	Absent	Broadly-ovate	Pink-white	205	39.3	2.7
20	SJG - 11 – 20	30.56	38.4	Present	Ovate	White	190	34.3	4.33
21	SJG - 11 – 21	17.96	21.76	Absent	Ovate	Pink-white	190	23.6	2.23
22	SJG - 11 – 22	17.2	20.13	Present	Ovate	White	190	42.3	3.9
23	SJG - 11 – 23	8.26	28.73	Present	Ovate	White	190	35.3	2.73
24	SJG - 11 – 24	12.66	28.2	Absent	Broadly-ovate	White	190	42.3	3.4
25	SJG - 11 – 25	9.3	25.66	Absent	Ovate	Pink-white	190	35.6	3.66
26	SJG - 11 – 26	22.76	40.86	Present	Ovate	Pink-white	205	43	4.4
27	SJG - 11 – 27	7.26	32.86	Absent	Broadly-ovate	Pink-white	190	35	2.6
28	SJG - 11 – 28	10.13	30.76	Absent	Ovate	Pink-white	205	39	2.86
29	SJG - 11 – 29	20.4	15.2	Absent	Broadly-ovate	Pink-white	190	37.3	3.56
30	SJG - 11 – 30	18.1	34	Absent	Ovate	White	190	43	4.1
31	SJG - 11 – 31	14.6	20.2	Absent	Ovate	White	190	37	2.66
32	SJG - 12 – 01	17.3	18.63	Present	Ovate	Pink-white	190	43	3.8
33	SJG - 12 – 02	13.53	15.2	Present	Broadly-ovate	Pink-white	190	41.6	2.83
34	SJG - 12 – 03	24.96	21.23	Absent	Ovate	Pink-white	190	37	2.66
35	SJG - 12 – 04	31.16	39.56	Present	Ovate	Pink-white	190	34.3	4.13
36	Yamuna Safed (G- 1)	21.26	38.06	Present	Broadly-ovate	Pink-white	205	37	4.2
37	Yamuna Safed (G-282)	22.9	29.1	Absent	Ovate	Pink-white	190	45	3.93
38	Yamuna Safed (G-323)	20.86	28.5	Absent	Ovate	Pink-white	205	44	3.83
39	G – 408	21.1	25.96	Absent	Ovate	White	190	41	3.6
40	Yamuna Safed (G-50) (check)	6.46	19.5	Absent	Broadly-ovate	Pink-white	190	48.6	2.83
41	Agri found Parvati (G-313) (check)	30.46	15.56	Present	Ovate	Pink-white	205	44	2.73
	Mean	16.72	25.45	-	-	-	193.2	38.5	3.35
	S.E. ±	2.48	2.59	-	-	-	-	8.5	0.4
	C.D.(5%)	6.99	7.3	-	-	-	-	23.8	1.12
	C.V.	25.73	17.66	-	-	-	-	38.32	20.63

colour, four categories emerged, out of which, 6 genotypes showed green colour foliage, 11 genotypes showed dull green foliage, 14 genotypes showed light green and 10 genotypes were having bright dark green foliage. G-408 had dull dark green foliage colour. On the basis of crop duration, the genotypes were harvested in two lots *i.e.*, one at 190 days after sowing and second at 205 days after sowing, thereby showing a difference of 15 days with a mean value of (193.20days). 8 genotypes including check Yamuna Safed (G-50) namely SJG-11-07, SJG-11-12, SJG-11-17, SJG-11-19, SJG-11-26, SJG-11-28, G-408 and Yamuna Safed(G-282) were harvested 15 days late *i.e.*,at 205 days after sowing as compared to rest of the genotypes which were harvested at 190 days after sowing. Variability with respect to the ability of formation of aerial bulbils (propagating material) is concerned, 12 genotypes including check Agrifound Parvati (G-313) and Yamuna Safed (G-50) showed the ability to produce aerial bulbils (Table 2). Similar variability in germplasm was observed by Singh and Chand, 2003, Monpara *et al*., 2005, Hosamani *et al*., 2010 and Singh *et al*., 2012.

Table 2: Cont..........

S.No.	Foliage colour	Leaf length (cm)	Leaf type	Number of leaves/ plant	Plant height (cm)	Pseudostem length (cm)	Total soluble solids (ºB)	Yield / ha (q)
1	Bright dark green	25.73	Spreading &Broad	7.6	37.5	2.4	24.5	71.73
2	Bright dark green	27.2	Spreading &Broad	9.7	38.73	4	23.86	77.2
3	Green	37	Erect & Narrow	6.9	50.53	3.56	23.76	73.56
4	Green	32.5	Erect & Broad	7.6	39.3	3.3	24.26	83.86
5	Dull green	34.9	Prostate & Broad	10	47.03	2.7	25.4	88
6	Dull green	29.36	Prostate & Broad	6.8	45.36	3.33	23.93	58.2
7	Bright dark green	30	Prostate & Broad	8.1	46.43	4.56	24.76	79.6
8	Bright dark green	28.86	Prostate & Broad	5.8	39.33	2.93	22.8	90.63
9	Dull green	25.13	Erect & Broad	8.3	34.03	2.66	23.9	90.8
10	Light green	29.5	Erect & Broad	7.9	36.8	2.5	24.1	134.96
11	Dull green	28.26	Erect & Broad	8.4	33.16	2.13	24.8	68.23
12	Light green	25.93	Prostate & Broad	8.2	35.5	3.16	23.6	84.86
13	Bright dark green	32.73	Prostate & Broad	7.7	47.6	2.53	23.96	60.66
14	Light green	31.2	Erect & Broad	7.86	38.6	3.7	26.1	50.63
15	Light green	35.8	Erect & Broad	7.76	52.1	3.2	25.1	53.33
16	Light green	30.2	Erect & Broad	6.1	39.7	4	24.4	37.1
17	Bright dark green	15.4	Prostate & Broad	5.5	22	1.86	24.16	36.23
18	Light green	31.8	Prostate & Broad	8.4	38.3	2.1	22.8	55.86
19	Bright dark green	22.83	Erect & Narrow	5.3	33.4	2.53	24.66	83.5
20	Dull green	21.3	Spreading &Broad	5.5	31.5	4.5	23.53	119.53
21	Light green	19.23	Erect & Broad	4.8	27.13	3	26.4	57.26
22	Light green	22.86	Erect & Broad	8.1	32.06	3.46	24.56	62.7
23	Light green	21.56	Erect & Narrow	5.7	28.5	3.66	23.6	79
24	Dull green	29.66	Spreading &Broad	7.03	40.13	4.8	23.2	77.3
25	Light green	22.8	Erect &Broad	6.5	34.96	4.16	23.6	79.86
26	Light green	22.66	Erect & Narrow	5.9	32.2	3.5	24.3	127
27	Light green	25.86	Erect & Broad	6.56	38.26	3.43	23.23	102.33
28	Light green	21.6	Erect & Broad	8.2	25.83	2.73	23.9	95.63
29	Light green	21.66	Erect & Narrow	6.6	30.47	3.46	24.56	47.36
30	Dark green	22.03	Erect & Narrow	6.3	30.76	3.33	24.33	116.6
31	Green	25.53	Erect & Broad	7.6	33.1	3.16	23	73.3
32	Green	25.6	Spreading &Broad	6.7	38.26	2.26	22.23	128.9
33	Dull green	24.73	Erect & Narrow	5.8	36.73	3.4	24.2	49.33
34	Dull green	29.9	Spreading &Broad	7.9	40.63	2.43	27.7	100.83
35	Green	32.5	Erect & Broad	9.3	41.6	2.7	29.86	88.53
36	Dull green	34.5	Erect & Narrow	6.53	49.76	1.76	23.73	59.16
37	Bright dark green	35.66	Spreading &Broad	8	48.16	1.83	23.7	58
38	Dull green	31.3	Erect & Broad	7.5	38.73	3.06	25.2	47.3
39	Dull dark green	25.3	Prostate & Broad	5.9	31.1	3.1	24.33	123.06
40	Bright dark green	28	Prostate & Broad	6.1	45.66	4.7	24.9	70.73
41	Green	20.93	Erect & Broad	6.16	26.6	3.36	24.1	78.46
	-	27.3	-	7.13	37.5	3.14	24.36	78.56
	-	3.1	-	1.07	2.59	0.61	1.41	11.76
	-	8.74	-	N.S	7.31	1.73	N.S	33.52
	-	19.71	-	26.07	11.99	33.87	10.03	26.25

An insight into the magnitude of variability present in a crop species is of utmost importance as it provides basis for effective selection. More the variability in germplasm, more is the chance for selecting desirable genotypes (Vavilov, 1951). Most of the economic traits are quantitative in nature, exhibit continuous variation under the control of both heritable and non heritable factors and effective selection would therefore depend upon the relative heritable portion(Fisher, 1918). In the present investigation, PCV was observed to be higher than the corresponding GCV for all the characters studied (Table 3). High estimates of PCV were observed for average weight of cloves (44.35%), average weight of bulbs (35.19%), yield /ha (38.81%), dry matter content (34.75%),plant height (21.62%) and leaf length (24.64%). However, the differences were narrow which implied their relative resistance to environmental variations. It also described that genetic factors were predominantly responsible for expression of these attributes and selection could be made effective on the basis of phenotypic performance. The traits which showed high phenotypic and genotypic coefficient of variation are of

Table 3: Estimates of various genetic parametersforvarious characters in garlic genotypes

Character(s)	Mean ± S.E.	Range	PCV (%)	GCV(%)	h^2(%) Broad sense	GA (%)	GA (% of mean)
Average weight of bulb (g)	25.45 ± 2.59	8.56 – 43.40	35.19	30.44	74.80	13.80	54.23
Average weight of 10 cloves (g)	16.72 ± 2.48	6.46 – 31.16	44.35	36.12	66.30	10.13	60.60
Dry matter content (%)	3.85 ± 0.85	2.36 – 5.10	34.75	16.15	21.60	0.59	15.46
Equatorial diameter (cm)	3.35 ± 0.40	2.23 – 4.40	25.06	14.22	32.20	0.55	16.62
Leaf length (cm)	27.30 ± 3.10	15.4 – 37.0	24.64	14.79	36.04	4.99	18.29
Number of leaves / plant	7.13 ± 1.07	4.80 – 10.00	27.38	8.37	9.30	0.37	5.27
Pseudostem length (cm)	3.14 ± 0.61	1.76 – 4.80	37.06	15.05	16.59	0.39	12.59
Plant height (cm)	37.50 ± 2.59	22.00 – 52.10	21.62	17.99	69.23	11.56	30.83
Total soluble solids (°B)	24.36 ± 1.41	22.23 – 29.86	9.84	1.97	4.00	0.19	0.81
Yield/ha (q)	78.56 ± 11.76	36.23–134.90	38.81	28.59	54.00	34.08	43.37

Table 4: Estimates of genotypic (G) and phenotypic (P) correlation coefficients among various characters in garlic genotypes

Character(s)		Average weight of 10cloves (g)	Dry matter content (%)	Equatorial diameter (cm)	Leaf length (cm)	Number of leaves/ plant	Plant height (cm)	Pseudostem length (cm)	Total soluble solids (°B)
Average weight of 10 cloves (g)	(G)	-							
	(P)	-							
Dry matter content (%)	(G)	-0.178*	-						
	(P)	-0.03	-						
Equatorial diameter (cm)	(G)	0.748**	-0.528**	-					
	(P)	0.389**	0.073	-					
Leaf length (cm)	(G)	0.173	-0.048	0.480**	-				
	(P)	0.093	0.035	0.127	-				
Number of leaves/ plant	(G)	0.405**	-0.276**	0.690**	0.15	-			
	(P)	0.016	-0.038	0.17	0.337**	-			
Plant height (cm)	(G)	0.045	-0.172	0.356**	0.222*	0.859**	-		
	(P)	0.018	0.002	0.181*	0.618**	0.202*	-		
Pseudostem length(cm)	(G)	-0.252**	-0.146	-0.171	-0.190*	-0.599**	0.046	-	
	(P)	-0.045	0	0.031	-0.091	-0.085	0.002	-	
Total soluble solids (°B)	(G)	-0.282**	-0.334**	0.187*	-0.299**	-0.269**	-0.06	0.842**	-
	(P)	0.221*	0.005	0.01	0.079	0.073	0.048	0.016	-
Average weight of bulb (g)	(G)	0.478**	0.103	0.898**	0.211*	0.256**	0.114	-0.026	-0.220*
	(P)	-0.278**	0.074	0.409**	0.054	0.128	0.049	-0.041	-0.004

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

economic importance and there is scope for improvement of these traits through selection. Results of Marey *et al.*, 2012,Yadav *et al.,* 2012 and Gashua *et al.,* 2013 also suggested for selection of traits with high GCV and PCV in any crop improvement programme.

Heritability

Heritability in broad sense ranged from (4.00% to 74.80%). High estimates of heritability in broad sense (Table 3) were recorded for characters like plant height (69.23%), average weight of cloves (66.3%), yield/ hectare (54.00%), leaf length (36.04%), equatorial diameter (32.20%) and average weight of bulbs (74.8%) indicating that selection for such characters be fairly easy because traits would be least influenced by environmental modifications and selections based on phenotypic performance would be reliable (Singh *et al.*, 2012 and Yadav *et al.,* 2012).

Genetic advance

It is the improvement over the base population that can potentially be made from the selection. It is the function of the heritability of the traits, the amount of phenotypic variation and the selection differential (s) that the breeder uses. The estimates of heritability and genetic advance should always be considered simultaneously as high heritability is not always associated with high genetic gain (Johnson *et al.*, 1955). Burton (1952) suggested that GCV along with heritability give the best picture of the genetic advance to be expected from selection. The estimates of genetic advance as percent of mean ranged from 0.81% to 60.60 % for total soluble solids and average weight of 10 cloves, respectively (Table 3). This indicates that selection from top 5% of the base population could result in an advantage of 0.81 to 60.60% over base population mean. High genetic advance coupled with high heritability was obtained for average weight of cloves, average weight of bulb, plant height and yield/ha. Hence due to additive gene action selection for these characters is likely to be more effective (Panse *et al.,* 2013).The characters like number of leaves/ plant, leaf length, pseudo stem length, dry matter content, total soluble solids and equatorial diameter showed low heritability coupled with high to low genetic gain and GCV depicting that these characters were governed by non-additive genes and would not be effective. The above results were confirmed to the earlier reports of Panthee *et al*. (2006),Morsey *et al*. (2011), Singh *et al*. (2012) and Barad *et al*. (2012).

Table 5: Estimates of genotypic (G) and phenotypic (P) path coefficients of various characters on bulb weight in garlic genotypes

Character (s)		AWC	DM	ED	LL	NOL	PH	PSL	TSS	CAWB
Average weight of 10 cloves (g)	G	0.95	-0.169	0.71	0.164	0.385	0.043	-0.239	-0.219	0.478**
	P	0.106	-0.003	0.041	0.009	0.008	0.002	-0.004	0.023	0.278**
Dry matter content (%)	G	-0.102	0.575	0.304	-0.027	-0.158	-0.099	-0.084	-0.192	0.103
	P	-0.001	0.036	0.002	0.011	-0.001	0.001	0.001	0.006	0.074
Equatorial diameter (cm)	G	0.314	-0.221	0.419	0.201	0.289	0.149	-0.071	0.078	0.898**
	P	0.089	0.016	0.228	0.029	0.039	0.041	0.007	0.002	0.409**
Leaf length (cm)	G	0.022	-0.006	0.061	0.127	0.146	0.155	-0.024	-0.038	0.211*
	P	-0.004	-0.001	-0.006	-0.051	0.017	-0.031	0.004	-0.004	0.054
Number of leaves / plant	G	-0.156	0.106	-0.266	-0.444	-0.386	-0.331	0.231	-0.49	0.256**
	P	0.001	-0.003	0.013	0.027	0.08	0.016	-0.006	0.005	0.128
Plant height (cm)	G	0.01	-0.038	0.079	0.272	0.191	0.222	0.01	-0.013	0.114
	P	-0.009	-0.002	-0.003	-0.012	-0.004	-0.02	-0.002	-0.001	0.049
Pseudostem length (cm)	G	-0.033	-0.019	-0.022	-0.025	-0.079	-0.006	-0.133	0.112	0.026
	P	0.005	0.005	-0.001	0.009	0.003	-0.001	-0.029	-0.001	-0.041
Total soluble solids (B°)	G	-0.402	-0.104	0.058	-0.094	-0.398	-0.018	0.263	-0.313	-0.220*
	P	-0.011	-0.002	-0.001	-0.003	-0.003	-0.002	-0.002	-0.049	-0.004

Residual effect (G) = 0.659 ; Residual effect (P) = 0.821

Phenotypic and genotypic correlation

The studies revealed significant and positive association of average weight of bulb with number of leaves / plant, leaf length and equatorial diameter at both phenotypic and genotypic levels (Table 4).Negative and significant correlation with average weight of bulb was shown by total soluble solids at genotypic levels. Significant and positive correlation of plant height was observed with number of leaves, leaf length and equatorial diameter at both genotypic and phenotypic levels and results are supported by the findings of Marey *et al*. (2012), Panse *et al*. (2013) and Dhall and Brar (2013). Significant positive correlation of number of leaves/plant with equatorial diameter and average weight of cloves was observed at genotypic level and with leaf length at phenotypic level. Similarly, significant but negative correlation of number of leaves / plant was observed with pseudo-stem length, total soluble solids and dry matter content at genotypic levels. Leaf length showed positive and significant correlation with equatorial diameter and negative but significant correlation with total soluble solids at genotypic levels. The results are in accordance with the results reported earlier by Naruka and Dhaka (2004) and Singh *et al*. (2006). Pseudostem length was significantly and positively correlated with total soluble solids but negatively with average weight of cloves.Average weight of cloves/bulb showed positive and significant correlation with equatorial diameter, whereas negative and significantly correlated with dry matter content and total soluble solids.Significant positive correlation was observed of equatorial diameter with total soluble solids butsignificant negative correlation with dry matter content. On the other hand, dry matter showed positive significant correlation with total soluble solids.The results of Vatsyayan *et al*. (2014) and Desai *et al*. (2015) are in agreement with the present study.

Path coefficient analysis

It is a powerful tool which enables partitioning of the given relationship in its further components. *i.e.,* it enables partitioning of total correlation coefficient into direct and indirect effects. In the present investigation, path coefficient analysis was carried out for eight characters under study using genotypic and phenotypic correlation coefficients and taking average bulb weight as dependant variable (Table 5).Positive direct effect of average weight of 10 cloves/bulb (0.950),dry matter (0.575), equatorial diameter (0.419),leaf length (0.127) and plant height (0.222) on average weight of bulb was observed and the results are in propinquity with Mohanty (2001) and Agarwal *et al*. (2009). These characters exhibit the significant correlation with average weight of bulb, thus their contribution towards yield cannot be ignored. However, highest negative direct effect was observed in number of leaves/plant (-0.386), TSS (-0.313) and pseudo stem length (-0.133) on average weight of bulb.The positive indirect effect on average weight of bulb was recorded for equatorial diameter *via*.,average weight of cloves/bulb (0.710), number of leaves/ plant *via*., average weight of 10 cloves (0.385)and equatorial diameter *via*., dry matter content (0.304).This indicated that indirect effect was the cause of correlation and the indirect causal factors are to be considered simultaneously for selection. The findings of Hosamani *et al*. (2010) in garlic, Degewione *et al*. (2011) in shallot and Dhall and Brar (2013) also in garlic supported the present study.

The present investigations indicated that there is a good scope for garlic improvement through selection of suitable traits among the genotypes in this region of J&K.

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