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Studies on genetic divergence in garlic *(Allium sativum* L.) germplasm

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Abstract
The present investigation entitled **"**Studies on genetic divergence in garlic germplasm. in garlic *(Allium sativum* L.)". The experiment was executed at Main Experiment, Station of Department of Vegetable Science, NDUAT Kumarganj Faizabad UP during *Rabi* season 2015-2016, with following objectives (1) to work out direct and indirect effects of different traits on yield and (2) to work out genetic divergence in garlic germplasm. The experimental material for the present study consisted of eighty genotypes, with plot size of 2.0 × 0.60 m^2 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), 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 (%).
The maximum positive direct effect on bulb yield per plant was exerted by number of cloves per bulb, weight of clove, total soluble solids, neck thickness of bulb, width of leaf and number of leaves per plant. It is suggested that selection for these traits will directly increase bulb yield per plant. The maximum inter-cluster distance was observed between cluster I and cluster IV which suggested that members of these two clusters are genetically very diverse to each other. The level of variation found in the genotypes showed great potentiality for improvement of garlic

Keywords: Genetic divergence in garlic, germplasm

Introduction
Garlic (*Allium sativum* L.) having diploid chromosome number 2n=2x=16 belongs to the family Amaryllidaceae (Alliaceae); known as Lahsun in Hindi, is one of the important bulb crop grown in India. It has long been recognized as a valuable spice and condiments in India. It is a frost hardy bulbous, erect annual herb with narrow flat leaves and bears small white flowers and bulbils (Janick, 1979) [4]. 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. The leaves are simple, long, flat and linear. The flowers are small and white, arranged in round umbels mixed with small bulbils. The entire umbels are enclosed in a tear-drop shaped membranous spathe. Flowers are usually sterile. The seed stalk bears terminal inflorescence, which in terms bear bulbils instead of flowers. The shoot of garlic become flat and finally aborts after the development of bulbils in the inflorescence (Kothari and Shah, 1974) [6]. The history of garlic dates back to the time immemorial original abode of garlic is said to be Central Asia and Southern Europe, especially Mediterranean region. Garlic has long been known as cultivated plant in India and China. It was carried out to the western hemisphere by the Spanish, Portuguese and French. The major garlic growing countries are Spain, Egypt, France, Mexico and Brazil. Asia shared major part in total world's garlic production. China, Korea, Spain, Egypt and USA are the major garlic growing countries. China ranks first in area and production followed by India and Korea republic. 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, 2015-16).

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.

The concept of path analysis was given by Wright (1921) but the technique was first used by Dewey and Lu (1959) [3]. Path coefficient analysis is simply standardized partial regression coefficient which split the correlation coefficient into the measures of direct and indirect effect on independent variable. In other words it measures the direct and indirect contribution of various independent characters on dependent character. It also estimates residual effect. Path coefficient analysis is useful in indirect selection. Garlic being an important crop need an attention about genetic improvement.

Material and Method

The present investigation entitled "Studies on genetic divergence in garlic germplasm. (*Allium sativum* L.)" was carried out at the Main Experiment Station, Department of Vegetable Science, NNPG Collage Faizabad (U.P.), India during *Rabi* 2015-16. The detail of materials used & methods employed during the present investigation has been referred in the subsequent paragraphs.

The experiments were conducted at Main Experiment Station, Department of Vegetable Science, Narendra Deva University of Agriculture and Technology, (Narendra Nagar) Kumarganj, Faizabad (U.P.) India in well leveled field having proper drainage facilities. This vegetable farm is situated in the main campus of the university on left side of Faizabad-Raebareili road at a distance of 42 km away from main city of Faizabad district. Geographically the experimental site (Kumarganj, Faizabad) falls under humid sub-tropical climate and is located at 26.47° N latitude and 82.12° Elongitude at an altitude of 113 meter above the mean sea level. Geographically, it falls in the north east gangetic alluvial plains of eastern (U.P.)

The experimental material of garlic used in the present study were, the collections from different places of Uttar Pradesh. Eighty genotypes have been used in the present study. The list of genotypes is given below-

The Design of experiment Augmented block design and 80 genotypes evaluate in 7 blocks with spacing 30cm x 10cm.

Result and Discussion

The details of direct and indirect effects to different characters on bulb yield per plant (g) at phenotypic & genotypic level are as follows:

The highest direct positive effect towards bulb yield per plant (g) was observed for number of cloves per bulb (0.4235) followed by number of leaves per plant (0.1736), plant height (0.1126), neck thickness of bulb (0.0477), weight of clove (0.0362) at phenotypic level.

However, T.S.S. (-0.1707) followed by length of clove (-0.1241), length of leaf (-0.1075), width of leaf (-0.0637), diameter of bulb (-0.0419) and diameter of clove (-0.0395) had exerted negative direct effect on bulb yield per plant.

The number of leaves per plant via number of cloves per bulb (0.1479) followed by length of cloves via number of cloves per bulb (0.1423), diameter of bulb via number of cloves per bulb (0.1004), plant height via number of clove per bulb (0.0996), T.S.S. via number of cloves per bulb (0.0792) and length of leaf via number of cloves per bulb (0.0263) had exerted maximum positive indirect effect on bulb yield per plant.

Table 1: Direct and indirect effects of 11 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)	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. (%)	Correlation with Yield per plant (g)
Plant height (cm)	0.1126	0.0784	-0.0614	-0.0184	-0.0175	0.0034	0.0996	-0.0395	0.0001	0.0058	-0.0505	0.1124
Number of leaves per plant	0.0508	0.1736	-0.0123	-0.0143	-0.0165	0.0004	0.1479	-0.0445	-0.0006	0.0023	-0.0333	0.2535
Length of leaf (cm)	0.0643	0.0199	-0.1075	-0.0080	-0.0115	0.0137	0.0263	-0.0257	0.0012	-0.0001	-0.0216	-0.0489
Width of leaf (cm)	0.0326	0.0389	-0.0135	-0.0637	-0.0093	0.0121	-0.0390	-0.0220	-0.0039	0.0030	-0.0063	-0.0712
Diameter of Bulb (cm)	0.0470	0.0684	-0.0294	-0.0141	-0.0419	0.0003	0.1004	-0.0357	-0.0024	-0.0001	-0.0065	0.0860
Neck Thickness of Bulb (cm)	0.0079	0.0015	-0.0308	-0.0162	-0.0003	0.0477	-0.0012	0.0141	0.0013	0.0011	-0.0322	-0.0070
Number of cloves per Bulb	0.0265	0.0606	-0.0067	0.0059	-0.0099	-0.0001	0.4235	-0.0417	-0.0013	0.0079	-0.0319	0.4327
Length of Clove (cm)	0.0359	0.0623	-0.0222	-0.0113	-0.0121	-0.0054	0.1423	-0.1241	0.0002	0.0003	-0.0357	0.0301
Weight of Clove (g)	0.0002	-0.0029	-0.0036	0.0068	0.0028	0.0017	-0.0156	-0.0006	0.0362	-0.0016	0.0092	0.0326
Diameter of Clove (cm)	-0.0166	-0.0100	-0.0002	0.0048	-0.0001	-0.0013	-0.0849	0.0009	0.0015	-0.0395	0.0308	-0.1146
T.S.S. (%)	0.0333	0.0338	-0.0136	-0.0023	-0.0016	0.0090	0.0792	-0.0259	-0.0019	0.0071	-0.1707	-0.0536

Residual effect = 0.8621

Table 2: Direct and indirect effects of 11 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)	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)	-1.2833	0.5377	0.3506	0.1351	0.4119	-0.0376	0.0981	-0.1989	0.0605	-0.0026	0.0570	0.1287
Number of leaves per plant	-0.9416	0.07329	0.0550	0.0994	0.2627	0.0094	0.1388	-0.0993	-0.0752	0.0016	0.0384	0.2219
Length of leaf (cm)	-0.9766	0.0875	0.4607	0.0430	0.2551	-0.0305	0.0118	-0.1287	0.0717	0.0603	0.0198	-0.1260
Width of leaf (cm)	-0.6556	0.2755	0.0749	0.2643	0.2119	-0.0258	-0.0546	-0.1634	-0.0838	0.0407	0.0243	-0.0916
Diameter of Bulb (cm)	-1.0095	0.3676	0.2244	0.1070	0.5236	-0.0312	0.1413	-0.0915	-0.0908	-0.0204	-0.0049	0.1158
Neck Thickness of Bulb (cm)	-0.4304	-0.0615	0.1255	0.0608	0.1457	-0.1120	-0.0281	-0.0986	0.0085	0.1424	0.0953	-0.1524
Number of cloves per Bulb	-0.2753	0.2226	0.0119	-0.0316	0.1619	0.0069	0.4570	-0.1623	-0.0469	0.0740	0.0339	0.4521
Length of Clove (cm)	-1.8469	0.5267	0.4292	0.3126	0.3466	-0.0799	0.5367	-0.1382	0.0715	-0.3256	0.0872	-0.0802
Weight of Clove (g)	-0.1545	-0.1096	0.0657	-0.0441	-0.0945	-0.0019	-0.0426	-0.0196	0.5029	-0.0591	-0.0020	0.0406
Diameter of Clove (cm)	-0.0151	-0.0052	-0.1272	-0.0493	0.0488	0.0730	-0.1548	-0.2059	0.1361	-0.2185	-0.0328	-0.5510
T.S.S. (%)	-0.4333	0.1664	0.0539	0.0380	-0.0151	-0.0632	0.0916	-0.0713	-0.0058	0.0425	0.1689	-0.0274

Residual effect = 0.8082

However, diameter of clove via number of cloves per bulb (0.0849), plant height via length of leaf (0.0614), plant height via T.S.S. (0.0505), number of leaves per plant via length of clove (0.0445), plant height via length of clove (0.0395) and number of leaves per plant via T.S.S. (0.0333) had exerted negative indirect effects on bulb yield per plant.

Genetic divergence

The study of genetic divergence of sixty genotypes was done through Mahalanobis D^2statistics as described by Rao (1952). The results are being described as follows:

Distributions of genotypes in different clusters

The highest number of genotypes appeared in cluster I which contained eighteen genotypes, followed by cluster IV having thirteen genotypes, cluster II having twelve genotypes and cluster VII having teen genotypes, cluster VIII having eight genotypes followed by cluster IV and cluster IX having six genotypes and cluster III having four genotypes followed by cluster VII, which have three genotype respectively among all the clusters table-4.8.

Average intra and inter- cluster distances

The intra and inter - cluster distance among different clusters are given in table-4.9. The intra-cluster D^2 values ranged from 13.50 (cluster VI) to 21.88 (Cluster VII). The maximum inter- cluster value (39.85) was found between VII and IX. The minimum inter- cluster value was found between I and II (18.38) indicates that this group is more diverse.

Cluster means

The mean performance for all the characters in different clusters is presented in table-4.10.Cluster VII showed highest mean for plant height (69.974), number of leaves per plant (8.663), length of leaf (39.927), diameter of bulb (4.529),bulb yield per plant (26.824), number of clove per bulb (27.228). Cluster VI showed highest mean for width of leaf (2.001). Cluster III showed highest mean for neck thickness of bulb (1.635), total soluble solids (38.174). Cluster I showed highest mean for weight of clove (1.568). Cluster IV showed highest mean for diameter of clove (1.515).

Per cent contribution of thirteen characters towards total genetic divergence in garlic

A perusal of per cent contribution is presented in table-4.11 showed that diameter of bulb, neck thickness of bulb, length of clove, weight of clove, diameter of clove, width of leaf (0.031%) and number of leaves per plant (0.13%), contributed very low towards the divergence while, plant height was found for highest contribution (59.05%) followed by length of leaf (17.03%), number of clove per bulb (8.77%) total soluble solids (8.01%) and bulb yield per plant (6.99%) for total divergence among the available genotypes of garlic.

Table 3: Clustering pattern of eighty garlic genotypes on the basis of Non-hierarchical Euclidean Cluster Analysis for 12 characters

Cluster Number	Number of genotypes	Genotypes
I	18	NDG-2, NDG-22, NDG-21, NDG-71, NDG-10, G-41, NDG-8, NDG-1, NDG-3, NDG-4, G-282, G-50, NDG-70, NDG-73, NDG-12, NDG-15, NDG-23, NDG-55
II	12	NDG-7, NDG-16, NDG-11, NDG-72, NDG-14, NDG-18, NDG-46, NDG-41, NDG-40, NDG-58, NDG-57, NDG-61
III	4	NDG-13, NDG-67, NDG-68, NDG-69
IV	13	NDG-17, NDG-20, NDG-19, NDG-45, NDG-63, NDG-24, NDG-47, NDG-49, NDG-25, NDG-48, NDG-56, NDG-64, NDG-65
V	6	NDG-5, NDG-6, NDG-9, NDG-75, NDG-77, NDG-77
VI	10	NDG-26, NDG-32, NDG-43, NDG-42, NDG-50, NDG-62, NDG-74, NDG-51, NDG-52, NDG-53
VII	3	NDG-29, NDG-30, NDG-27
VIII	8	NDG-31, NDG-44, NDG-54, NDG-36, NDG-66, NDG-59, NDG-60, NDG-28
IX	6	NDG-33, NDG-38, NDG-39, NDG-34, NDG-35, NDG-37

Table 4: Estimates of average intra and inter-cluster distances for 9 clusters in garlic

	I Cluster	II Cluster	III Cluster	IV Cluster	V Cluster	VI Cluster	VII Cluster	VIII cluster	IX cluster
I Cluster	14.428	18.386	23.204	20.519	22.817	22.775	36.222	26.513	31.702
II Cluster		14.395	23531	20.694	21.535	21.762	31.946	23.983	31.881
III Cluster			14.033	25.117	30.494	33.757	39.852	34.122	38.154
IV Cluster				14.754	30.458	24.017	36.969	24.380	39.451
V Cluster					13.657	22.050	32.154	27.508	26.312
VI Cluster						13.508	35.455	20.409	29.675
VII Cluster							21.881	26.194	32.304
VIII Cluster								14.346	23.480
IX Cluster									18.995

Table 5: Cluster means for 12 characters in Garlic

Characters	Plant height (cm)	Number of leaves per plant	Length of leaf (cm)	Width of leaf (cm)	Diameter of Bulb (cm)	Neck Thickness 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)	T.S.S. (%)
I Cluster	64.522	7.959	35.954	1.982	4.044	1.4462	24.467	22.785	2.366	1.568	1.503	33.812
II Cluster	61.844	8.274	33.108	1.695	4.029	1.397	23.560	21.151	2.378	1.328	1.498	32.356
III Cluster	62.842	8.418	35.540	1.885	3.793	1.635	22.749	20.230	2.417	1.212	1.432	38.174
IV Cluster	42.533	6.762	28.148	1.641	3.244	1.529	19.741	17.197	2.302	1.320	1.515	34.644
V Cluster	51.592	7.956	29.327	1.659	3.652	1.443	22.525	19.992	2.201	1.203	1.438	35.234
VI Cluster	68.222	8.200	36.789	2.001	4.048	1.605	22.670	22.233	2.465	1.236	1.292	37.180
VII Cluster	69.974	8.663	39.927	1.173	4.529	1.219	26.824	27.228	2.579	1.247	1.413	36.305
VIII Cluster	59.867	7.743	31.852	1.779	3.661	1.583	22.423	20.844	2.260	1.151	1.221	36.766
IX Cluster	52.523	7.639	30.610	1.228	3.574	1.366	25.400	23.534	2.331	1.415	1.508	32.997

Table 6: Percent contribution of 12 characters towards total genetic divergence in garlic

S. No.	Source	Contribution (%)
1	Plant height (cm)	59.05
2	Number of leaves per plant	0.13
3	Length of leaf (cm)	17.03
4	Width of leaf (cm)	0.03
5	Diameter of Bulb (cm)	0.00
6	Neck Thickness of Bulb (cm)	0.00
7	Bulb Yield per plant (g)	6.99
8	Number of cloves per Bulb	8.77
9	Length of Clove (cm)	0.00
10	Weight of Clove (g)	0.00
11	Diameter of Clove (cm)	0.00
12	T.S.S. (%)	8.01

In the present study, the highest positive direct effect on bulb yield per plant was exerted by number of cloves per bulb followed by weight of clove, total soluble solids, length of bulb, neck thickness of bulb, width of leaf and number of leaves per plant. Similar results have been reported by Singh *et al*. (1981) [9], Singh (1984) [10], Barman *et al.* (1998) [2], Yadav *et al.* (2007) [14] and Tiwari *et al.* (2014) [13]. However, length of leaf, diameter of bulb, length of clove, diameter of clove and plant height 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, weight of clove via length of clove, weight of clove via width of leaf, length of bulb via plant height, length of bulb via number of cloves per bulb and width of leaf via number of leaves per plant, had exerted maximum positive indirect effects on bulb yield per plant. Similar results have been reported by Selvaraj *et al*. (1997) [7].

The studies on genetic divergence among sixty genotypes of garlic were carried out by using Mahalanobis D^2 statistics'. In present investigation eighty genotypes of garlic were grouped in nine distinct non- over lapping clusters. This indicates presence of considerable diversity in the genotypes. The major clusters in the above mentioned genetic divergence analysis contained frequently the genotypes of heterogeneous origin. Although the genotypes of same origin or geographic region were also found to be grouped together in the same cluster. The instances of grouping of genotypes of different origin or geographic region in same cluster were frequently observed. This suggested that there is no parallelism between genetic and geographic diversity.

In the present study, genotypes are divided into nine clusters. Cluster I had maximum number of genotypes followed by clusters IV, cluster II, cluster VI, cluster VIII, cluster V, cluster IX, cluster III and cluster VII. Similar results have been reported by Khar *et al*. (2006) [5].

The maximum intra-cluster D^2 value observed in cluster VII. The maximum inter-cluster distance was observed between cluster VIII and cluster XI, which suggested that members of these two clusters are genetically very diverse to each other. Fallowed by cluster VI to cluster VII, cluster IV to VII, cluster IV to VI, cluster II to VI and cluster II to VII were very high inter-cluster value. The minimum inter-cluster D^2 value was recorded in case of cluster I and cluster II followed by cluster II and cluster III. The higher inter-cluster distance indicated greater genetic divergence between the genotypes of these clusters, while, lower inter cluster values between the clusters suggested that the genotypes of the clusters were not much genetically diverse from each other. Similar results were also reported by Khar *et al*. (2006) [5].

Cluster VII showed maximum mean values for the plant height, number of leaves per plant, length of leaf diameter of bulb, bulb yield per plant, number of clove per bulb and length of clove. Cluster VI showed highest mean for width of leaf. Cluster III showed highest mean for neck thickness of bulb, and total soluble solids (TSS). Cluster I showed highest mean for weight of clove. Cluster IV showed highest mean for diameter of clove, whereas cluster I showed highest mean for number of cloves per bulb and cluster IV showed highest mean for weight of clove. Similar finding were also reported by Singh *et al.* (2013) [1]. A perusal of per cent contribution table-4.11 showed that plant height was found for highest contribution followed by length of leaf, number of cloves per bulb and total soluble solids for total divergence among the available genotypes of garlic, while number of leaves per plant, bulb yield per plant, diameter of bulb, contributed very low towards the divergence. Similar results were reported by Patil *et al.* (2013) [8] and Shashidhar and Dharmatti (2005) [12].

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