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Character association and path analysis of yield and yield attribute traits in garlic (*Allium sativum* L.) under western Tarai region of Dhampur

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Abstract
The present investigation was carried out during 2020-21 at Agriculture Farm, Ranjit Singh Memorial Post Graduate College, Dhampur, Bijnor, affiliated with Mahatma Jyotiba Phule Rohilkhand University, Bareilly, Uttar Pradesh, India. The investigation was laid out in randomized block design (RBD) with three replications. The treatment consisted of 21 cultivars of Garlic. Observations were recorded on vegetative attributes The mean squares due to genotypes were highly significant for all the characters. The higher magnitude of variability character association and path analysis at phenotypic as well as genotypic levels observed for diameter of bulb, length of clove, bulb yield per plant and number of cloves per bulb, suggesting additive gene action. Moderate pathanalysis at phenotypic as well as genotypic level observed in case of plant height, length of leaf and neck thickness. High variability coupled with high genetic advance as per cent of mean was observed for diameter of bulb and bulb yield per plant. This indicates that these traits were less in" uenced by environment under Dhampur condition.

Keywords: Genotypes of garlic diameter of bulb, length of clove, bulb yield per plant

Introduction
Garlic (*Allium sativum* L.) (2n=16) commonly known as garlic belongs to Amaryllidaceae family. Its close relatives include the onion, shallot, leek, chieve and rakkyo. Among cultivated alliums garlic is the 2nd most widely used vegetable after onion (*Allium cepa* L.). The origin of garlic is thought to be in Central Asia (India, Afghanistan, West China and Russia) and spread to other parts of the world through trade and colonization (Tindal, 1986). Garlic is grown for its edible bulbs. The bulbs can be eaten fresh, cooked, processed or saved for seed Hannan and Sorensen. The garlic bulb contains small bulblets called as cloves. It is easy to grow and can be grown year-round in mild climates. While sexual propagation of garlic is possible, nearly all of the garlic in cultivation is propagated asexually, by planting individual cloves in the ground. In colder climates, cloves are planted in the autumn, about six weeks before the soil freezes, and harvested in late spring or early summer. Garlic is the second most important spice crop in India. The total production of garlic in India is 1611 metric tons with area 317 hectare (NHB). But in India the average yield of garlic is 5.06 t/ha, which is very low as compared to the world production. The present research work entitled**,** "studies on the character association and path analysis of yield and yield attribute traits in garlic (*Allium sativum* L.) Under Westrn Tarai region Dhampur, Bijnor (U.P)" keeping all these thing and importance of the garlic crop in mind, the present investigation was aimed with the following objectives:

- To assess the variability for bulb yield and yield traits in garlic
- To determine the direct and indirect effects of the yield attributing characters on the yield
- To select the best genotype/variety.

Review of literatures
This chapter aims at represent some review of the past research works that are related to the present study. A few researches have been done on garlic production in India. Some important studies on garlic production, There are following.

Bhatt *et al*. (2017) [2], evaluated 16 diverse Indigenous genotypes of garlic for assessment of genetic variability and character association including path coefficient analysis, heritability and genetic advance for twelve yield contributing traits and revealed that both at genotypic and phenotypic levels, the gross bulb yield was significantly and positively associated with number

of cloves per bulb (p = 0.803, r = 0,807). ascorbic acid (p = 0.549. r = 0.572) and weight of 10 uniform cloves (rp-0.486, rg - 0.487).

General description

According to Figliuolo *et al*. (2001); Ipek *et al*. (2003) garlic belongs to the genus Allium family Alliaceae, which includes important vegetable crop such as onion (Allium cepa), leek (A. ameloprisum) and shallots (A. asacloncum). Garlic is a diploid species (2n = 2x = 16) of obligated apomixis and propagated vegetatively.

Hector *et al*. (2012) [3], revealed that garlic is propagated asexually, but shows a high morphological diversity among cultivars. These cultivars have a wide range of adaptation to different environments. Like onion, garlic plants have thin tape shaped leaves about 30 cm long. Roots reach up to 50 cm depth or little more. Heads or bulbs are white skinned, divided into sections called cloves. Each head could have from 6 to 12 cloves, which are covered with a white or reddish papery layer or "skin". Similarly Kamenetsky *et al*., (2001) revealed that sexual propagation in garlic is expected to facilitate the exchange of genetic traits from one genotype to another and to improve garlic cultivars through classical breeding. Garlic does not produce true seed but it is propagated by planting cloves. Each bulb usually contains a dozen or more cloves and planted separately. Select only larger outer cloves of the best garlic bulbs for planting because larger cloves yield larger size and mature bulbs at harvest.

McLaurin. (2012) [4], suggested not to divide the bulb until ready to plant; early separation decreases yields. Select "seed bulbs" that are large, smooth, fresh, and free from disease. To plant garlic properly, dig a hole or trench, place the unpeeled clove gently into the hole with the pointed side up (the scar [stem] end down) and cover the clove with soil. Setting the cloves in an upright position ensures a straight neck.

Growth and development

McLaurin. (2012) [4], found in his conducted experiment leaves will begin to turn brown and tops will fall, indicating maturity. Stop irrigation at this time to avoid bulb discoloration and bulb rots. To ensure bulbs are fully mature, remove the top layer of soil over the top of a few bulbs and check bulbs to make sure they are fully differentiated (division of bulb into distinct cloves). Harvest the garlic when 1/3 to 1/2 of the leaves have died back in this manner.

Genetic variability

The development of an effective plant breeding program is dependent upon the presence of genetic variability in the material. The efficiency of selection depends upon the magnitude of genetic variability present in the plant population. Thus, the success of genetic improvement in any character depends on the nature of variability present in the germplasm of that character. Hence an insight into the magnitude of variability present in the gene pool of a crop species is of almost important to a plant breeder for starting a judicious plant breeding programme. Many biometrical techniques are available which are commonly used to assess the variability in plant population. These are simple measures of variability (range, mean, standard deviation, variance, standard error, coefficient of variation), variance component analysis, D2 statistics and metroglyph analysis. The simple measures of variability especially the coefficient of variation partitions the variation into phenotypic, genotypic and environmental components and determines the magnitude of these components for various traits.

Mishra *et al*. (2018) [5], evaluated 80 indigenous garlic genotypes for genetic variability and reported that leaf length had significant and positive correlation with plant height, number of leaves per plant, bulb equatorial diameter and bulb yield per plant which indicated that selection for these traits would be more effective in the improvement of bulb yield.

Rahman and Das. (1985) [6], analyzed correlation coefficient in garlic and indicated that bulb yield/plant had highly positive significant correlation with number of leaves/plant, leaf length, and bulb diameter. Bulb diameter also had positive significant association with number of leaves/plant and leaf length

Sharma *et al*. (2016) [7], evaluated one hundred and thirty-one genotypes of garlic using twelve Morpho-agronomic traits were carried out at SVPUAT, Meerut, during Rabi-2014. result reveals that high heritability was obtained for all traits (>60%) and high heritability coupled with moderate genetic advance was recorded for clove weight, bulb weight per plant, pseudostem height, polar diameter of bulb equatorial diameter of bulb and number of cloves per bulb. The genotypes viz.PG-20, K-1, GHC-1, TG-1, CFG-3, G-50 are noticed with good export potential and can be utilized for improvement of garlic germplasm.

Siktberg *et al*. (2006) [8], suggested that a period of cold followed by a period of light and heat is needed for proper growth of garlic. Although garlic requires low temperatures in preparation for bulb development, increased day length and heat are necessary for bulbs to begin forming. Paredes *et al*., (2007) revealed that garlic is a species of vegetative propagation, showing high morphological diversity. Besides, its clones have specific adaptations to different agro-climatic regions.

Garlic shows wide morphological and agronomic variations in characteristics such as color and size of the bulb, plant height, number and size of the cloves, days to harvesting, resistance to storage capacity, dormancy and adaptation to agro-climatic conditions (Figliuolo *et al*., 2001)

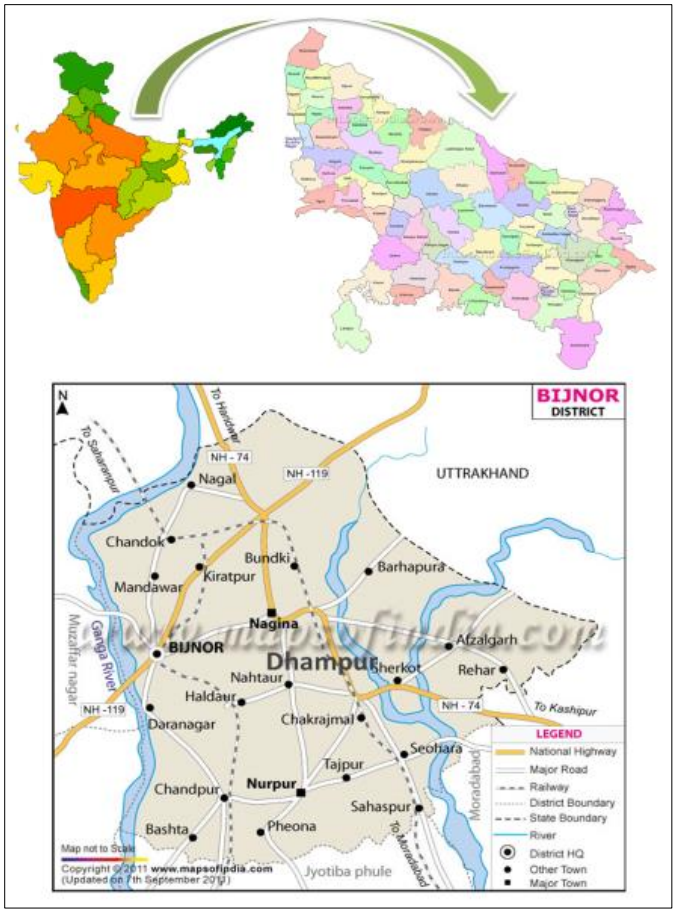
Sabur and Mollah. (1993) [9], under look a study on constraints of production and marketing of species in Bangladesh. The study revealed that the real price of garlic, onion and turmeric increased significantly by 3.83 percent, 3.58 percent and 3.17 percent respectively during the study period. They examined that the storage facilities for spices, particularly cold storage, were limited and seasonal price variations largely dependent on the perishability of spices.

Gebremichael *et al*. (2019) [1], studied path coefficient analysis revealed that plant height, leaf number, leaf length, bulb length, bulb diameter, mean bulb weight, biological yield, total dry biomass and harvest index exhibited positive direct effect on total bulb yield.

Yaso. (2007) [10], studied the phenotypic correlation and path coefficient analysis between bulb weight and various component characters. He recorded significant and positive correlation between bulb weight and each of plant height, number of leave per plant and time of maturing. Path coefficient analysis showed the plant height had high positive direct effect on bulb weight. The number of leaves per plant revealed moderate positive indirect effect on bulb weight.

Materials and Methods

This chapter deals with the information on the subject of materials and methods that were used in conducting the experiment. It consists of a short explanation of locations of the experimental site, soil characteristics, climate, materials used in the experiment, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural practices, harvesting, data recording procedure and statistical analysis etc., which are presented as follows. The experiment was conducted at the experimental field of Ranjit Singh memorial (PG) Collage, Dhampur, Bijnor (Uttar Pradesh) India during rabi season of the year 2020 to 2021. The location of the experimental site was situated at 29^0 15'27.5328 N latitude and $78^0$30'0.2196" E longitudes with an elevation of 235 meter from the sea level.



The plants were planted at a distance of 15 (cm) Row to Row and 10 (cm) Plant to Plant as per spacing of transplanting. Total number of treatment 21. Plot size 1.05m X 3m, Total number of plots 63, Net cultivated area 198.45 m^2 and gross cultivated area 423.15 m The following observations were recorded during the course of experimentation on following characters- Plant height (cm), Number of leaves/plant, Height of stem (cm)/plant, Height of stem (cm)/plant, Diameter of stem (mm)/plant, Fresh bulb weight (g)/plant, Dry bulb weight (g)/plant, Fresh bulb weight (g)/plant, Dry bulb weight (g)/plant, Polar Diameter of bulb/plant (cm), Equal Diameter of bulb/plant (cm), Yield (kg)/plot, Yield q/ha, T.S.S. (Brix 0) and Protein (%). The observations were recorded on five randomly selected plants of each row. Average of data from the sampled plant of each treatment was used for statistical analyses in order to draw valid conclusions. The statistical parameters like mean, range were calculated as per the standard methods of analysis.

Result and Discussion

The analysis of variance for the design of experiment indicated that the mean square due to phenotypes were highly significant for most of the characters. Correlation due to check were also highly significant for characters- Correlation coefficient is estimated between yield and other character at genotype and phenotypic levels to know the inter relationship among the characters. It provides information about the nature extent and direction of selection pressure to be applied. Yield is complex characters controlled by several yield contributing components and is highly influenced by environment factors consequently selection based on yield will not be much effective. Hence association of characters with yield is important for making selection in the breeding programme. It suggests the advantage of a scheme of selection for more then on character at a time. It the present study the estimates of phenotypic and genotypic correlation coefficient imparted that in general the values of genotypic correlation coefficient were higher in magnitude than their corresponding phenotypic ones as also reported by Barad *et al*. (2012). Plant height showed positive and highly significant correlations with height of stem (1.000), dry bulb weight (0.564), and protein (0.885) fresh bulb weight (0.828), equal diameter (0.804), diameter of stem (0.766) significant and positive correlation, Polar diameter (0.554) where negative correlation with number of leaves. Number of leaves/plant showed positive and highly significant correlations with Total soluble sugar (0.802).and negative correlation with height of leaves (0.162), equal diameter (0.110), Height of stem (0.089). Height of leaves/plant showed positive and highly significant correlations with Height of stem (0.951), bulb weight (0.913), protein (0.885), Fresh bulb weight (0.828), equal diameter (0.804), diameter of stem (0.766),and polar diameter (0.544) significant. Height of stem/plant showed positive and highly significant correlations with protein (0.918), dry bulb weight (0.889), equal diameter (0.804) significant, fresh bulb weight (0.798), and diameter of stem (0.657), polar diameter (0.641) significant, Diameter of stem /plant showed positive and highly significant correlations with fresh bulb weight (0.932), dry weight of bulb (0.882), protein (0.706) significant, equal diameter (0.620), and yield/plot (0.573), yield/hectare (0.565), T.S.S (0.521) significant. Fresh bulb/plant weight showed positive and highly significant correlations with dry bulb weight (0.978), protein (0.882), equal diameter (0.739), and polar diameter (0.700), yield/plot (0.519), yield/hectare (0.505), T.S.S (0.498) had significant. Dry bulb weight showed positive and highly significant correlations with, protein (0.943), equal diameter (0.820), polar diam0eter (0.736). Polar diameter showed positive and highly significant correlations with, protein (0.845), equal diameter (0.638), and T.S.S (0.565) significant. Equal diameter showed positive and highly significant correlations with Protein (0.817).Yield /plot showed positive correlations with yield/hectare (1.000), T.S.S (0.413), and protein (0.385).Yield/hectare showed positive correlations with T.S.S (0.401), and protein (0.376).T.S.S showed positive correlations with protein (0.297).

Table 2: Mean performance

s. no	Genotypes	Plant Height	Plant pseudo-stem height	Number of leaf	Leaf length	Leaf Width (mm)	Plant Pseudo-stem diameter	Equatorial Diameter of bulbs	Polar Diameter	No of cloves /bulb	Weight of fresh bulbs	Weight of Dry bulbs	Yield q/ha	Total soluble solid	Sulphur content %	Protein %
1	G-01	38.13	11.83	6.78	46.60	19.33	14.36	43.38	45.10	23.94	42.90	32.40	153.53	39.05	0.326	6.78
2	G-41	47.97	7.59	8.83	46.56	22.67	13.89	44.12	53.18	20.28	47.39	39.38	153.80	41.19	0.323	7.00
3	G-50	37.00	9.98	7.48	48.84	18.93	13.15	38.30	45.78	24.07	35.80	26.38	137.60	40.02	0.337	7.27
4	G-282	40.60	11.63	6.29	49.29	18.20	13.38	41.77	45.26	21.56	37.12	29.12	158.70	40.15	0.353	7.30
5	G-323	43.75	11.10	6.88	48.93	19.27	14.18	41.23	47.10	23.80	39.90	31.27	158.60	40.29	0.330	6.67
6	G-384	39.70	12.80	7.42	48.75	21.93	15.38	40.67	46.70	24.35	40.92	31.54	152.23	43.01	0.350	7.10
7	G-386	36.82	9.53	7.50	48.74	21.60	13.16	39.62	43.67	18.37	34.83	27.43	158.80	41.28	0.330	6.63
8	Nainital Local	43.40	11.54	7.10	49.17	19.53	13.40	42.71	42.87	21.11	35.47	31.33	111.44	35.11	0.357	6.27
9	NG-3162	35.76	11.03	6.67	46.44	18.47	11.68	38.76	42.67	21.77	27.67	22.53	126.75	37.74	0.353	6.47
10	Panth lohit	53.90	10.90	6.93	55.18	20.47	15.33	45.62	45.40	23.20	56.93	44.65	163.88	39.60	0.330	6.87
11	G-189	42.95	12.68	7.17	46.11	20.10	14.12	42.12	45.20	25.65	38.62	30.89	179.93	39.38	0.333	6.67
12	NG-3149	40.50	9.98	7.66	52.01	21.33	14.60	38.87	49.38	19.81	36.38	30.18	156.49	39.95	0.327	6.37
13	NG-3166	39.23	10.68	6.78	45.75	18.33	11.73	36.39	44.12	22.30	27.00	24.95	132.22	38.61	0.327	6.50
14	NG-3174	42.65	12.64	6.27	48.81	17.53	12.34	34.34	42.49	24.49	29.74	21.56	111.00	39.82	0.350	6.43
15	NG-3181	38.43	10.42	6.85	47.86	18.73	12.78	42.28	45.79	20.42	38.58	32.12	132.17	37.31	0.327	6.50
16	Sweta white	41.01	10.89	6.78	47.00	18.13	11.85	36.81	43.33	14.80	26.73	18.00	111.11	40.32	0.323	6.33
17	Godwaripurpl	40.65	11.67	7.12	48.43	19.00	12.80	37.61	44.20	19.78	35.20	24.93	148.14	38.92	0.323	6.37
18	phule Baswant	51.47	10.87	6.89	50.79	18.07	12.30	43.76	44.93	18.98	42.13	30.80	116.40	36.88	0.323	6.23
19	GG-4 White	41.57	10.63	5.76	45.22	17.07	11.69	36.94	43.07	16.62	28.80	16.80	89.94	40.19	0.320	6.40
20	VL Garlic-1	46.33	10.50	7.07	50.28	19.13	13.41	42.12	47.87	22.45	38.80	31.87	121.48	37.79	0.320	6.40
21	VL Garlic-2	45.67	11.43	6.53	48.56	18.47	12.03	40.75	48.57	19.24	37.33	28.93	121.69	37.98	0.323	6.57
	Mean	42.26	10.97	6.99	48.54	19.35	13.22	40.39	45.56	21.29	37.06	28.91	137.90	39.27	0.333	6.63
	Max	35.76	7.59	5.76	45.22	17.07	11.68	34.34	42.49	14.80	26.73	16.80	89.94	35.11	0.320	6.23
	Min	53.90	12.80	8.83	55.18	22.67	15.38	45.62	53.18	25.65	56.93	44.65	179.93	43.01	0.357	7.30
	SE(d)	1.56	0.41	0.25	1.80	0.67	0.49	1.47	1.54	0.78	1.32	1.05	4.99	1.44	0.011	0.25
	C.D. at 5%	3.17	0.84	0.50	3.65	1.35	1.00	2.99	3.12	1.58	2.69	2.12	10.13	2.91	0.023	0.50
	C.V. (%)	4.53	4.63	4.33	4.55	4.22	4.56	4.47	4.14	4.47	4.38	4.43	4.43	4.48	4.19	4.54

Conclusion

The present investigation entitled **"**studies on the character association and path analysis of yield and yield attribute traits in garlic (*Allium sativum* L.) Under Westrn Tarai region Dhampur, Bijnor (U.P)" was carried out at Agriculture Farm, Ranjit Singh Memorial (PG) College, Dhampur, Bijnor (Uttar Pradesh) during 2020-2021. Dhampur (affiliated with Mahatma Jyotiba Phule Rohilkhand University, Bareilly, Uttar Pradesh) in a randomized block design (RBD) with three replications. A total of 21 cultivars of garlic had been taken as an experimental material for the present investigation.

- Cloves of garlic were sown to the main field in Randomized Complete Block Design (RCBD) with three replications. Data on various agro-morphological traits such as plant height (cm), Number of leaf, Leaf length, Leaf Width (mm), Plant Pseudo-stem diameter, Equatarial Diameter of bulbs, Polar Diameter, No of cloves /bulb, Weight of fresh bulbs, Weight of Dry bulbs, Yield quantal/ha, Total soluble solid, Sulphur content %, Protein %.
- Based on mean performance genotype G-189, Panth Lohit,G-386, G-282 and G-223 exhibited high value for characters that showed significant positively correlation with yield q/ha.
- The high phenotypic and genotypic correlation of variation (<20%) was observed for dry bulb weight and fresh bulb weight, number of leaves per plant, pseudo-stem height, pseudo-stem diameter, number of cloves per bulb, leaf length, leaf width, plant height polar diameter, equatorial diameter, T.S.S, Protein, sulphur content indicating high degree of variability in these characters and suggest the possibility for yield improvement through selection of these traits.
- The broad sense heritability (>60%) was higher number of cloves/bulb, plant height, polar diameter, plant pseudostem diameter, weight of dry bulb, number of leaf, equatorial diameter, weight of fresh bulb, sulphur content, yield q/ha, plant pseudostem height, leaf length, T.S.S, leaf width, protein could mean that these characters are mainly controlled by the genetic factors and selection based on these characters will be rewarding.
- Correlation coefficient studies indicated that higher phenotypic correlation than the corresponding genotypic ones, indicating the phenotypic expression of the correlation were influenced by the environmental factor among the various traits. weight of dry bulb (gm) showed with weight of fresh bulbs, bulb yield per hectare, number of cloves/bulbs, plant pseudo stem height, plant height, plant psuedostem diameter, number of leaves, leaves width, polar diameter, protein, sulphur content and total soluble solids. Which implies these characters were the prime contributing characters to yield q/ha. All suitable combination of these traits should be considered while selecting for higher yield genotypes.
- Improvement of yield q/ha could be achieved by exercising direct selection of number of leaf, weight of dry bulbs, protein, total soluble solids, plant pseudostem diameter, leaf width, leaf length, number of leaf, equatorial diameter polar diameter, as these characters

showed significant positive and positive direct effect on yield q/ha coupled with high heritability and high genetic advance as percent of mean.

- In mahalanobis D^2 analysis the accession were grouped in to 21 clusters. Among the five cluster. The cluster I contained six genotype (9,13,14,16,17,19) cluster II had one cluster (10) cluster III had Eight genotype (1,3,4,5,7,11,12.) cluster IV included five genotype (8,15,18,20,21) whereas cluster V accommodated one genotype (1). This envisaged that the genotype grouped within a particular cluster were more or less genetically similar to each other are apparent wide diversity was mainly due to the remaining genotype distributed over rest of the other cluster.
- The Maximum inter cluster distance (8.964) was recorded between cluster V and I. followed by cluster II and I (8.806). On the other hand minimum inter cluster distance (1.001) was found between cluster II and II followed by duster between V and III (5.817). The highest intra cluster distance (8.964) was observed in cluster VI followed by II (7.154) indicating a wider genetic diversity between the genotypes in these groups. Cluster V (8.806) had the lowest intra cluster distance indicating close relationship and similarity for most of the traits.
- The highest cluster mean value were observed in cluster-II for yield q/ha (163.88),leaf length (55.18),polar diameter (45.40),plant height (53.90), total soluble solids (39.60) and equatorial diameter of bulb (45.62). cluster-III yield (156.98), leaf length (48.66), polar diameter (46.02), equatorial diameter (40.74), plant height (39.93), total soluble solids (40.39) and weight of fresh bulbs (38.31). cluster-V yield (153.80), leaf length (46.56), polar diameter (53.18), equatorial diameter (44.12), plant height (47.97), total soluble solids (41.19) and weight of fresh bulbs (47.39). cluster-IV yield (120.64), leaf length (49.33), polar diameter (46.01), plant height (45.06), weight of fresh bulbs (38.46) and total soluble solids (37.01). cluster- I yield (119.86), weight of fresh bulbs (29.19), leaf length (46.94), plant height (40.15), equatorial diameter of bulbs (36.81), polar diameter (43.31), and total soluble solids (39.27).
- Characters such as weight of dry bulbs (44.34%) toward total divergence followed by weight of fresh bulbs (38.42%), Yield quintal/ha (32.68%), number of cloves/bulbs (24.87%), plant height (20.56%), plant pseudo-stem height (19.46%), plant pseudo-stem diameter (15.11%), number of leaves (15.52%), Equatorial Diameter of bulbs (11.79%), polar diameter (8.36%),leaves width (13.11%), leaves length (5.30%), Sulphur content % (3.07%), and Total soluble solids % (4.64%), the minimum values were recorded for protein (5.49%) can be used for selection parents from distinctly placed cluster to obtain higher production.

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