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Assessment of Genetic Divergence in Long Day Onion (*Allium cepa* L.) through Principal Component and Single Linkage Cluster Analysis

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Abstract: To assess the nature and magnitude of genetic diversity in long day onion germplasm by using the principal component analysis and single linkage cluster analysis an experiment was carried out with 34 onion genotypes. High coefficient of variation with wide range in traits indicated an appreciable variability in germplasm. Genotypes were classified into seven principal components having Eigen value > 1, cumulatively accounted for 83.87% of total variability. Principal Component - I contributed for 24.73% of total variation for followed by principal component-II (15.27%). PC-I had high positive loading for bulb weight (0.401), marketable yield (0.338), total bulb yield (0.401) and PC-II had high positive loading for plant height (0.412), PC-III for high T.S.S. (0.276) PC -IV for A grade bulbs (0.436), PC-V for polar diameter of bulbs (0.514), PC-IV negatively loaded with purple blotch (-0.461) and PC-VII for narrow neck thickness (-0.515). Plotting PC-I against PC-II differentiated CITH-O-13, CITH-O-4, CITH-O-22, CITH-O-19, CITH-O-9, CITH-O-6 and CITH-O2 as most divergent genotype. On the basis of single linkage cluster means cluster-I was most important for average bulb weight, minimum bolters, high marketable bulb percentage high marketable and total bulb yield whereas cluster -II was important for maximum number of leaves/plant and minimum neck thickness. Highest inter-cluster distance was observed between cluster II and Cluster-I (873.5%). Most divergent genotypes with high inter cluster distance could be the most appropriate parents for crop improvement in onion.

Keywords: Genetic diversity, Onion, Principal component analysis, Single linkage cluster analysis.

INTRODUCTION

Onion is an important vegetable crop used by all the sections of people, round the year throughout the world for its distinct flavour and health healing properties. It is a photosensitive crop and forms bulbs at certain day length. Long day onion requires 14 hours or more day length

to initiate the bulbing. In India, majority of growing area is under short day onion except in hilly region. Long day onion is grown in temperate region of India with productivity ranging from 10 to 23 t/ha. Though it covers large temperate area from Jammu and Kashmir to Arunachal Pradesh but efforts on varietal improvement programme on long day onion are very limited. There is no commercial long day variety available for cultivation except some old introductions like Yellow Globe and Brown Spanish. Farmers use their own seed without caring isolation distance to maintain the purity which leads to a great variability in shape and size of bulb with inherent low yield.

The magnitude of genetic diversity in onion germplasm is a critical component in breeding for new cultivar. Selection of genetically diverse parents in breeding programme on the basis of divergence would be more promising to get the heterotic F₁, and to create a broad spectrum of variability in segregating generation (Meena and Bahadur, 2015). Presence of genetic diversity play a vital role in plant breeding for getting higher yield, uniformly desired quality and resistance to biotic and abiotic stresses. A systematic understanding of genetic diversity in different traits is essential for targeted breeding programme. There are numerical taxonomic techniques available to classify the variation pattern at inter and intra specific level (Ario and Odulaza, 1999). Multivariate analysis is an effective tool for characterization and classification of plant genetic resources, when a large number of accessions are assessed for several traits (Peter and Matrinelli, 1989). Different type of multivariate analysis such as principal component analysis (PCA) and single linkage cluster analysis (SLCA) are used to identify groups of accessions that have desirable traits for breeding and assessing the pattern of variation in germplasm collection. PCA enables easier understanding of impact and relationship among the different traits. However PCA alone would not give an adequate character representation in term of relative importance when multiple characters are considered simultaneously (Shalini *et al.*, 2003). To complement the results of such multivariate analysis, Single Linkage Cluster Analysis (SLCA) is employed to classify the variation. It is an agglomerative technique which shows the patterns of exact genotype position in population. (Ariyo and Odulaza, 1999) by sorting them in distinct group. Thus this study is aimed to identify the major characters responsible for variation among the onion genotypes with a view to group accessions and for identifying the potential parental stocks within the group of local germplasm by employing the multivariate analysis.

MATERIALS AND METHODS

Thirty four long day onion accessions (*Allium cepa* L.) including two varieties collected from growing hot spot of Kashmir valley and conserved at active germplasm site of ICAR-Central Institute of Temperate Horticulture, Srinagar (J&K) were evaluated (Table 1). The seedlings of 45 day old were transplanted in main field during rabi season. Each accession was grown in ten rows of two metre length with a spacing of

10x15 cm. The experiment was conducted in randomized block design with three replications. Geographical position of the experimental site lies between latitude of 34005 N and longitude of 74050 E at an altitude of 1640 MSL. The average maximum and minimum temperature were 19.630 C, 6.520 C respectively with annual precipitation of 160.72 mm and relative humidity 58.35%, evaporation 2.45mm. The soil characteristics viz. pH= 6.81 and EC = 0.36 dSm⁻¹ were recorded during the cropping season. Recommended uniform agronomic and cultural practices were adopted to obtain better expression of phenotypic characters. Data was recorded on nineteen quantitative traits. Disease severity rating was measured on 0-5 scale - (0 grade - No disease, 1 grade - 1-10%, 2 grade -11- 20%, 3 grade -21-30%, 4 grade -31-50% and 5 grade -51-100%). Whereas, pest (thrips) damage (1-5 scale) - (1 -1-20% foliage damage, 2- 21-40 foliage damage, 3-41-60% foliage damage, 4-61- 80% foliage damage and 5-81-100% foliage. The genotypes with <5% infestation was considered immune, 6-10% infestation resistant, 10-20 infestation moderately resistant, 21-40% infestation moderately susceptible, 41-60% infestation susceptible >60% infestation considered highly susceptible. Data collected on the quantitative characters were analyzed using SAS Microsoft Windows 9.2 (SAS Institute, 2011), employing the method outlined by Steel and Torrie (1980) using statistical XL STAT-2011. Principal Component Analysis and Single Linkage Cluster Analysis (SLCA) were used for the determination of genetic variation and percentage similarity within the genotypes. Eigen - Vectors and principal component score were used to assess the relative discriminatory power of its axis and their associated characters. The cluster procedure was used to produce distinct groups of 34 genotypes on the basis of genetic relationship while using the character variation. Average intra-cluster distance was calculated by the following formula as suggested by Singh and Choudhary (1985). SLCA summarized the position of accessions into a dendrogram at an interval of 5% level of dissimilarity starting from 100 % level of dissimilarity (Kendall, 1980).

Table1
Accessions with their geographical information used in study

Genotype	Collection site	Latitude	Longitude	Altitude (Meter)	Genotype	Collection site	Latitude	Longitude	Altitude (Meter)
CITH-O-1	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-17	Srinagar	34.08 ⁰	74.79 ⁰	1585.01
CITH-O-2	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-18	Baramulla	34.198 ⁰	74.36 ⁰	1590.00
CITH-O-3	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-19	Baramulla	34.198 ⁰	74.36 ⁰	1590.00
CITH-O-4	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-20	Baramulla	34.198 ⁰	74.36 ⁰	1590.00
CITH-O-5	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-21	Baramulla	34.198 ⁰	74.36 ⁰	1590.00
CITH-O-6	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-22	Baramulla	34.198 ⁰	74.36 ⁰	1590.00
CITH-O-7	Budgam	34.63 ⁰	74.04 ⁰	3199.99	CITH-O-23	Baramulla	34.198 ⁰	74.36 ⁰	1590.00
CITH-O-8	Gandharbal	34.23 ⁰	74.78 ⁰	1619.10	CITH-O-24	Shopian	34.81 ⁰	75.01 ⁰	2057.00
CITH-O-9	Gandharbal	34.23 ⁰	74.78 ⁰	1619.10	CITH-O-25	Shopian	34.81 ⁰	75.01 ⁰	2057.00
CITH-O-10	Gandharbal	34.23 ⁰	74.78 ⁰	1619.10	CITH-O-26	Badipora	34.50 ⁰	74.68 ⁰	1578.00
CITH-O-11	Gandharbal	34.23 ⁰	74.78 ⁰	1619.10	CITH-O-27	Bandipora	34.50 ⁰	74.68 ⁰	1578.00
CITH-O-12	Gandharbal	34.23 ⁰	74.78 ⁰	1619.10	CITH-O-28	Kulgam	33.65 ⁰	75.02 ⁰	1738.88
CITH-O-13	Srinagar	34.08 ⁰	74.79 ⁰	1585.01	CITH-O-29	Kulgam	33.65 ⁰	75.02 ⁰	1738.88
CITH-O-14	Srinagar	34.08 ⁰	74.79 ⁰	1585.01	CITH-O-30	Kupwara	33.65 ⁰	75.02 ⁰	1738.88
CITH-O-15	Srinagar	34.08 ⁰	74.79 ⁰	1585.01	CITH-O-31	Kupwara	33.65 ⁰	75.02 ⁰	1738.88
CITH-O-16	Srinagar	34.08 ⁰	74.79 ⁰	1585.01	CITH-O-32	Srinagar	34.08 ⁰	74.79 ⁰	1585.01
Coral Red (check)	ICAR-DOGR Pune	-	-	-	Brown Spanish	ICAR-DOGR Pune	-	-	-

RESULTS AND DISCUSSION

The genotypes evaluated for all horticultural traits varied significantly (Table 2). The phenotypic variability expressed by range, standard deviation, and coefficient of variation. The plant height ranges from 63.33 to 91.66 cm. Genotype CITH-O-9 recorded highest plant height, whereas CITH-O-32 recorded lowest plant height (63.33 cm). Number of leaves ranged from 6.33 (CITH-O-9) to 14.0 cm (CITH-O-19). Polar diameter of bulb ranged from 5.18cm (CITH-O-7) to 11.97cm (CITH-O-13). Equatorial diameter of bulb ranged from 5.87cm (CITH-O-5) to 11.08 cm (CITH-O-8). Polar and equatorial diameter ratio reflects the bulb shape which is an important parameter indirectly related to yield storage life and market preference. The bulbs of genotype having < 1 Polar and equatorial diameter ratio (P: E) considered as flat and genotypes having P: E ratio 1 considered globe and those having P: E ratio > 1 were considered as torpedo. Genotype CITH-O-11, had P: E ratio 1, whereas CITH-O-4, CITH-O-32 and CITH-O-13 have < 1 P: E ratio and remaining genotypes were having > 1 P: E ratio. Neck thickness of bulb affects the storage life. Neck thickness ranged from 0.42 to 2.46 cm. The minimum neck thickness (0.42 cm) was observed with genotype CITH-O-7 , whereas CITH-O-19 had maximum neck thickness (2.46 cm). Bulb grade determines the market price and quality. A grade bulb ranged from 12 to 86.11 per cent (Table 3). Genotype CITH-O-12 recorded highest A grade percentage of bulbs. B grade

bulb ranged from 00 to 34.55 per cent. Double bulbs which are major drawback in onion production ranged from 00 to 34.28 percent. Total soluble solids important quality trait in onion ranged from 0.36 to 16 per cent. Genotype CITH-O-29 scored highest TSS (16 %) whereas minimum TSS(0.36%) was recorded with genotype CITH-O-5. Average bulb weight which is directly correlated with yield, ranged from 154.51 to 470.30 g. Genotype CISH-O-9 recorded the highest average bulb weight (470.30 g) whereas smallest bulb size was recorded with CITH-O-29 (154.51 g). Foliar disease of onion is major problem in long day conditions. The incidence of purple blotch ranged from 7.00 to 30.71%. Genotype CITH-0-29 has recorded highest infestation (30.31%) whereas, least infestation was observed with variety Brown Spanish (7%). Downy mildew infestation ranged from 13.48 to 30.50%. The lowest (13.48%) infestation of downy mildew was observed in genotype CITH-0-9 whereas highest infestation of was recorded with CITH-0-2 (30.50%). Thrips is major damaging insect in long day onion. Number of thrips/plant ranged from 7.66 to 31.00 / plant. The minimum infestation of thrips /plant was recorded with genotype CITH-0-6 (7.66/plant) whereas, maximum number of thrips / plant was observed with CITH -0-17 (31.00/plant). Premature bolting a burning problem in onion ranged from 0 to 3.66 % among the genotypes evaluated. The highest percent of bolting was observed in genotype CITH-0-11 (3.66%), whereas four teen genotypes recorded 0% bolting. Marketable bulb percentage is an important trait from economic point of view. The percentage of marketable bulb ranged from 48.26 to 100% . The lowest marketable bulb percentage (48.26 %) was recorded with genotype CITH-09 whereas CITH-0-28 had recorded 100 % marketable bulbs. Marketable bulb yield ranged from 331.28 to 1212.56 q/ha. The lowest marketable bulb yield was recorded with genotype CITH-0-31 (331.28 q/ha) whereas highest marketable bulb was recorded with CITH-0-8 (1212.56 q/ha). Total yield ranged from 494.5 to 1505.06 q/ha. Among the genotype evaluated, CITH-09 recorded highest total yield, whereas minimum total yield was observed with CITH-0-31. The genotype having the highest desirable traits may be utilised for crop improvement programme for a particular trait. Coefficient of variation (%) reflected the extent of variation for evaluated phenotypic traits was highest for double bulb percentage and B grades of bulbs, T. S. S and marketable bulb yield (q/h) . High coefficient of variation amongst studied traits indicated appreciable variability which is prerequisite of a crop improvement program. Similar type of variability was also reported by Arya et al. (2017). The observed variability found among the onion genotypes might be related to genetic makeup of genotype as per Kandil et al. (2010).

Table 2
Variation in quantitative traits of onion accessions

Characters	Range				Mean	Standard deviation	CV (%)
	Minimum		Maximum				
	Value	Genotype	Value	Genotype			
Plant height (cm)	63.33	CITH-O-32	91.66	CITH-O-9	80.09	5.92	12.92
No. of Leaves / plant	6.33	CITH-O-9	14.00	CITH-O-19	9.87	1.66	23.71
Polar diameter (cm)	5.18	CITH-O-7	11.97	CITH-O-13	7.44	1.23	20.58
Equatorial diameter (cm)	5.87	CITH-O-5	11.08	CITH-O-8	8.52	1.15	20.85
Polar Equatorial diameter ratio	0.55	CITH-O-11	2.03	CITH-O-4	0.89	0.26	25.82
Neck thickness (cm)	0.42	CITH-O-7	2.46	CITH-O-19	0.96	0.38	30.56
A Grade bulb (%)	12.00	CITH-O	86.11	CITH-O-12	58.71	15.95	37.05
B Grade bulbs (5)	0.00	CITH-O	34.55	CITH-O	13.96	10.39	60.16
C Grade bulbs (%)	0.00	CITH-O	33.00	CITH-O	6.53	8.42	51.04
Doubles (%)	0.00	CITH-O	34.28	CITH-O	16.05	11.48	66.97
TSS %	0.36	CITH-O-5	16.00	CITH-O-29	10.92	4.36	54.51
Average Bulb weight (gm)	154.51	CITH-O-29	470.30	CITH-O-9	289.08	82.29	34.99
Purple Blotch (%)	7.00	Brown Spanish	30.71	CITH-O-29	19.52	50.88	33.13
Thrips/plant	7.66	CITH-O-17	31.00	CITH-O-6	24.26	5.44	35.12
Downy mildew (%)	13.48	CITH-O-9	30.50	CITH-O-2	20.80	4.92	32.25
Bolters (%)	0.00	CITH-O-9	3.66	CITH-O-11	0.91	1.10	60.31
Marketable bulbs (%)	48.26	CITH-O-9	100.00	CITH-O-28	82.35	12.60	25.20
Marketable yield (q/Ha)	331.28	CITH-O-9	1212.56	CITH-O-31	765.09	251.74	41.52
Total Yield (q/h)	494.45	CITH-O-9	1505.06	CITH-O-31	925.07	263.32	34.99

Table 3

The Principal component latent vector for Eigen values and proportion of variance accounted for different components with respect of different traits

Characters	PC-I	PC-II	PC-III	PC-IV	PC-V	PC-VI	PC-VII
Plant height (cm)	-0.039	0.412	0.045	0.208	0.328	-0.215	0.018
No. of Leaves/ plant	-0.317	0.147	0.273	-0.001	0.192	-0.043	0.014
Polar diameter (cm)	-0.037	-0.315	-0.109	-0.262	0.514	-0.072	-0.162
Equatorial diameter(cm)	0.354	0.227	0.062	-0.018	-0.075	0.040	0.160
Polar Equatorial diameterratio	-0.204	-0.355	-0.168	-0.138	0.398	-0.108	-0.230
Neck thickness (cm)	0.040	0.288	0.283	-0.228	0.096	0.128	-0.515
A Grade bulb (%)	0.179	-0.111	0.278	0.436	0.234	-0.187	0.083
B Grade bulbs (5)	-0.208	0.034	0.346	-0.355	-0.111	0.250	0.081
C Grade bulbs (%)	-0.027	-0.336	-0.302	0.041	-0.403	-0.090	0.146
Doubles (%)	-0.243	0.198	-0.267	-0.325	-0.101	0.154	0.177
TSS %	-0.236	-0.142	0.276	-0.214	-0.135	-0.179	0.146
Average Bulb weight (gm)	0.401	0.034	-0.029	-0.309	0.104	0.014	0.022
Purple Blotch (%)	0.055	-0.082	0.198	-0.183	0.021	-0.461	0.376
Thrips/plant	-0.195	-0.170	0.305	-0.108	0.012	0.057	0.277
Downy mildew (%)	-0.006	-0.137	0.158	0.221	0.156	0.660	-0.002
Bolters (%)	-0.039	0.023	-0.331	0.029	0.322	0.280	0.564
Marketable bulbs (%)	0.148	-0.410	0.282	0.146	-0.098	0.137	0.030
Marketable yield (q /Ha)	0.388	-0.192	0.125	-0.199	0.025	0.083	0.063
Total Yield (q /h)	0.401	0.034	-0.029	-0.309	0.104	0.014	0.022
Eigen value	4.698	2.902	2.410	2.072	1.583	1.221	1.051
Variability (%)	24.726	15.271	12.686	10.904	8.333	6.424	5.530
Cumulative %	24.726	39.998	52.684	63.588	71.921	78.345	83.876

Based on degree of divergence 34 genotypes were grouped into 7 principal component having Eigen value >1 and cumulatively accounted for 83.87% of total variability (Table 4a and 4b). The PC-I contributed for 24.73% of total variation was positively loaded with bulb weight, marketable bulb percentage, total and marketable bulb yield. It was negatively correlated with number of thrips per plant, downy mildew infestation, (%) bolters and doubles, B and C grades bulbs. The PC-II reflected 15.27% of total variability and was positively loaded with plant height, neck thickness and negatively with downy mildew infestation. The PC-III was positively loaded with T.S.S. (%), number of leaves/plant and contributed 12.69 % of total variation. The 4th principal component contributed 10.90% of total variability was, associated with A grade bulb (%) and negatively correlated with purple blotch disease. The PC-V accounted 8.33% of total variation was positively loaded with polar diameter, Polar: Equatorial. Diameter ratios, bolter percentage and negatively loaded with C grade bulb percentage. Principal Component-VI contributed 6.42% of total variation and was positively correlated with downy mildew (%) but it was negative associated with purple blotch. PC-VII accounted for 5.53% of total variation was positively loaded with bolter percentage, purple blotch percentage, and number of thrips/plant and was negativity correlated with neck thickness.

The positive and negative loading of quantitative traits reflects the positive and negative correlation trend between the components and variables suggesting that these principle components may be used to summarise the variables. The traits with largest absolute value closer to unit within first component influence the cluster more than those to lower absolute value closer to zero. Thus in present study the differentiation of genotypes in different principal component was because of high contribution of few characters rather than small contribution of each character. The desirable characters loaded positively and undesirable characters loaded negatively in first seven PC's could be in consideration while selecting the genotype for appropriate traits and yield potential. The principal component analysis has also been used for showing the genetic diversity in many species (Ravindra et al., 2018; Singh et al., 2017). The Bi-plot of PC-I & PC-II indicated that the some isolated genotype clearly define the diversity among the evaluated germplasm. The genotype CITH-0-13, CITH-0-4, CITH-0-22, CITH-0-19, CITH-0-9, CITH-06, CITH-O-2 and variety Coral Red were most divergent (Fig 1) usually is customary to select one of the important variable from these identified groups for targeted improvement programme. Hence PC-I for higher total yield, PC-II for plant height, PC-III for high T.S.S, PC-IV for maximum A Grade bulb, PC-V for wider polar diameter of bulb, PC-VI for resistance to purple blotch, PC-VII for thin Neck thickness of bulb were ideal for selection. The results of present study are useful as it furnish the information about the group where certain traits are more important, allowing breeder to execute breeding for specific target. Biological implication of principal component analysis can be quantified by contribution of different variable in each PC as revealed by Eigenvector and cluster score at the component axis suggest that some relationship exist among the individuals with the cluster but not provided the exact position of genotypes in groups.

Table 4a
Cluster means for 19 characters in 34 onion genotypes
based on agglomerative hierarchical clustering analysis

Characters	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V
Plant height (cm)	63.33	83.00	79.66	79.33	80.00
No. of Leaves/ plant	7.33	12.00	10.33	8.33	11.00
Polar diameter (cm)	7.50	8.54	6.55	5.18	7.95
Equatorial diameter(cm)	7.16	5.87	9.32	9.48	8.99
Polar Equatorial diameter ratio	1.05	1.45	0.70	0.55	0.89
Neck thickness (cm)	0.98	0.66	1.21	0.42	0.88
A Grade bulb (%)	22.00	42.00	69.21	65.69	63.58
B Grade bulbs (%)	25.00	6.35	12.28	0.00	20.51
C Grade bulbs (%)	25.00	12.40	0.00	15.84	7.69
Doubles (%)	28.00	28.05	17.30	16.33	8.20
TSS %	15.06	9.50	14.00	2.23	14.10
Average Bulb weight (gm)	374.06	196.98	310.39	236.69	377.76
Purple Blotch (%)	8.24	10.26	13.09	8.39	9.10
Thrips/plant	24.66	21.33	24.00	9.33	29.00
Downy mildew (%)	16.08	19.96	20.16	18.06	17.01
Bolters (%)	0.00	1.18	1.21	2.13	0.00
Marketable bulbs (%)	92.66	71.94	82.70	83.66	91.79
Marketable yield (q/Ha)	1109.15	453.47	821.41	633.64	1109.59
Total Yield (q/h)	1197.01	630.34	993.24	757.40	1208.83

Based on single linkage cluster analysis genotypes were grouped into five clusters by quantifying their share and cluster means for all the traits (Table 4 a,b). The cluster-I and Cluster-III accommodated maximum number of genotype (9) followed by cluster II (8), Cluster-IV (7) and cluster -V(1) contributing 26.47, 23.53, 20.58 and 2.94%, of total population respectively. On the basis of cluster means, the cluster-I was important for high TSS (15.06%), marketable bulbs percentage (92.66%) powdery mildew (8.24%) and purple loch (16.08%) resistance. Cluster-II was important for plant height (83 cm) number of leaves/plant(12), polar diameter (8.54 cm) and P:E ratio (1.54) cluster-III was important A grade bulb percentage (69.21%)whereas cluster-IV was important equatorial diameter (9.48 cm),minimum neck thickness (0.42 cm) thrips resistance (9.33 thrips/ plant). Cluster -V was important for average bulb weight (377.76 g) marketable yield (1109.59 q/ha) and total yield (1208.83 q/ ha). The genotype of cluster having high means value of particular traits would contribute more positively in their off springs if used as a parent. Arya et al. (2017) and Singh et al. (2017) also suggest that clusters having high meanvalue of the traits may be used for hybridizationprogram to get better segregates.

Table 4b
Grouping of 34 onion genotypes into five clusters
based on agglomerative hierarchical clustering analysis

Characters	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V
Number of genotypes	9	8	9	7	1
% of total genotypes	26.47	23.52	26.47	20.28	2.94
Position of genotype	CITH-O-1	CITH-O-4	CITH-O-5	CITH-O-7	CITH-O-29
	CITH-O-2	CITH-O-14	CITH-O-6	CITH-O-13	
	CITH-O-3	CITH-O-16	CITH-O-10	CITH-O-15	
	CITH-O-8	CITH-O-21	CITH-O-11	CITH-O-17	
	CITH-O-9	CITH-O-22	CITH-O-12	CITH-O-19	
	CITH-O-18	CITH-O-24	CITH-O-20	CITH-O-25	
	CITH-O-27	CITH-O-30	CITH-O-23	CITH-O-28	
	CITH-O-32	CITH-O-31	CITH-O-26		
	Brown Spanish		Coral Red		

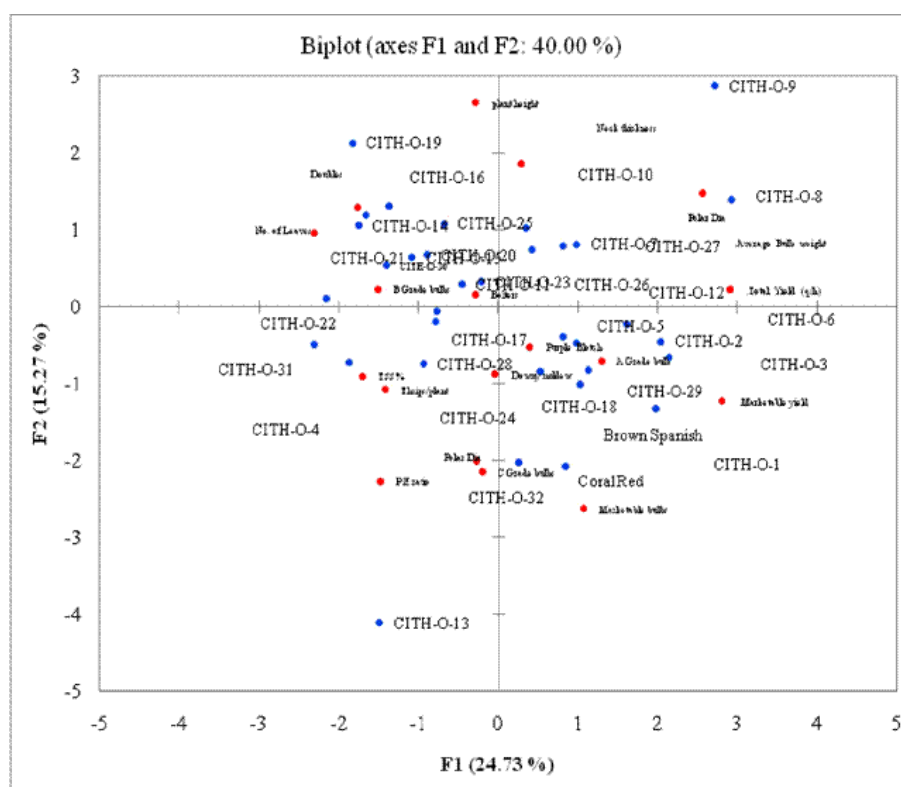


Fig. 1
 Bi-plot for 1st and 2nd PC for genotypes of onion in relation horticultural traits

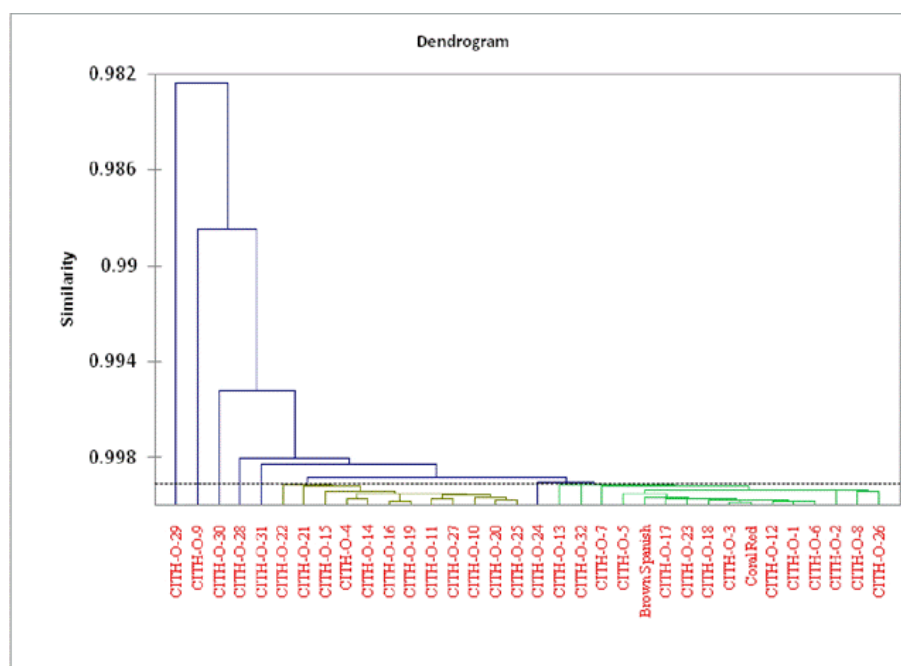


Fig. 2

Dendrogram depicting genetic relationship among 34 genotypes based on horticultural traits produced by complete linkage analysis (Scale-Euclidean distance at .05)

Proximity matrix obtained, suggest the resolution for 34 onion genotype distributed in five clusters with wide range of diversity for the traits (Table 5.) The highest inter cluster distance between cluster II and Cluster I (803.47%) followed by cluster-III and I (697.8) cluster V and cluster I (582.56). Based on convention that distantly related parents give better recombinants and hybrid. It could be expected that hybridization between genotype of these cluster will results high heterotic F_2 s and better recombinants in segregating generations. These genotypes of distant cluster could serve useful source of genes for different desirable traits in onion. The findings are in conformity with finding of Singh et al. (2017), Chattopadhyay et al. (2015) and Ravindra et al. (2018) who reported that genotypes among the cluster having high distance when used in hybridization programme will obtain a wide spectrum of variation in sergents.

Table 5
Average Inter and intra cluster distance

	Cluster-I	Cluster-II	Cluster-III	Cluster-IV	Cluster-V
Cluster-I	0.00	803.47	697.08	509.31	582.56
Cluster -II		0.00	488.05	334.36	435.95
Cluster-III			0.00	305.03	579.48
Cluster-IV				0.00	353.09
Cluster-V					0.00

Dendrogram obtained from single linkage cluster analysis by using the Euclidian distance depicted the clear relationship and exact position of

genotype in the clusters. All the genotype were distinct at 100 percent of dissimilarity and formed nine duster at 87% of dissimilarity, and formed five clusters at 57 of dissimilarity (Fig II). The dissimilarity ranged from 57 to 100% among the delineated genotypes enough to suggest the variability for crop improvement in onion. (Denton and Nwangburuka, 2011).

Genotypes CITH-0-29, CITH-0-26, CITH—8, CITH-0-24 and CITH-05 were divergent in cluster position on the basis of Euclidian distance which reflected higher distance among these genotypes and may be used for hybridization to get the better segregates. Singh *et al.*, 2013 and Santara *et al.*, 2017 also reported such variability by using the single linkage cluster analysis in Onion. This genetic diversity analysis would be useful to avoid the selecting parents from genetically homogenous cluster and maintain the broad genetic base for breeding programme in long day onion.

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