

Multivariate Hierarchical Diversity Analysis of Chrysanthemum (*Dendranthema grandiflora* Tzvelev) Genotypes

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ABSTRACT: Chrysanthemums have beautiful flowers with high ornamental value and rich genetic diversity. Usually univariate analytic tools utilized for diversity analysis. Thirty genotypes of Chrysanthemum were characterized based on multivariate hierarchical tools in present study during 2019 and 2020 cropping season at research farm of CCS Haryana Agricultural University, Hisar. Flower yield per plant expressed by Pusa Guldata followed by Pusa Shwet, Pusa Chitrksha whereas low yielders were Bicolor Aruba, Garden Beauty, Papaya Clever. Mostly significant positive correlation coefficient values had observed of flower yield per plant trait with Number of flowers per plant, number of buds per plant, Fresh weight of plant, dry weight of plant, plant spread whereas negative correlations of low magnitude were seen with stalk length, stem diameter, dry weight of flower. Four clusters of genotypes had been observed by multivariate hierarchical approach with 13.3, 40, 16.7 and 30 percent of total genotypes. Biplot analysis observed the first principal component (PC) accounted for 30.1% of the total variation as most of variations contributed by number of buds per plant, number of flowers per plant, fresh weight of plant, dry weight of plant, flower yield per plant and plant spread. Principal component two contributed 20.9% to the total variation as five traits, flower diameter, fresh weight of flower, plant height, dry weight of flower, fresh weight of plant were to contributed more to second PC. The multivariate hierarchical tools considered number of variables simultaneously for proper assessment of variability.

Keywords: Chrysanthemum, multivariate hierarchical, correlation and biplot analysis.

INTRODUCTION

Chrysanthemum (*Dendranthema grandiflora* Tzvelev) has been well established as one of the most important cut flower, garden flower, and ornamental crops at the world level (Kumar *et al.*, 2015; Singh *et al.*, 2019). Chrysanthemums have been associated with various international cultures, native of China, cultivated widely for the centuries for beauty, fragrance, and medicinal values (Anderson, 2006). Augmented with large showy flowers, rich flower colors, multiple variations, strong resistance, chrysanthemums have been observed in many countries (Negi *et al.*, 2019). The process of hybridization of dwarf cultivars with wild species through mixed pollination or open pollination made it possible to breed new chrysanthemums (Nguyen *et al.*, 2020). After generations of hybridization and selection, groundcover chrysanthemums were developed, and many outstanding cultivars were introduced for cultivation in urban landscapes successfully (Pawar *et al.*, 2020). The distinguishing features of groundcover chrysanthemums have been marked as of compact sizes, abundant

flowers, long bloom duration of rich colors as well as highly drought-tolerant (Singh *et al.*, 2017).

Mostly applied univariate analysis along with standard deviations of traits failed to provide a complete insight into the complex behavior of traits (Geleta, 2020). Multivariate statistical methods are appropriate tools for the analysis of the complex structure. Multivariate techniques have been used to estimate the genetic divergence between accessions, like biometric models, estimated by the Euclidean Distance (Ali *et al.*, 2021). Hierarchical clustering techniques with Ward's minimum variance method have been advocated (Jiangshuo *et al.*, 2019). Principal component analysis (PCA) in studies to evaluate the magnitude of genetic diversity among the genotypes reduced a large number of traits into a smaller set of traits that have the maximum contribution in differentiating the genotypes. Looking at the importance and commercial potential of the crop there is an urgent need to characterize the available variability, its evolution to identify potential genotypes. The present study was designed to study growth, flowering and yield contributing traits in various genotypes of chrysanthemum.

MATERIALS AND METHODS

The thirty genotypes of Chrysanthemum were evaluated at CCS Haryana Agricultural University, Hisar situated at 29°10'North latitude and 75°46'East longitude with an elevation of 215.2 meters above Mean Sea Level. Genotypes were evaluated under field trials in randomized block design with three replications during 2019 and 2020 cropping seasons. The sowing was done in 1.5m × 1.5m plot size with 30cm × 30cm spacing. The soil of the experimental site was alkaline (pH 8.5) having 5.1g kg⁻¹ organic carbon and 130 kg available nitrogen ha⁻¹. Well rotten farmyard manure @ 5 kg/m² was uniformly mixed as a basal dose in the soil a fortnight before transplanting of seedling. The fertilizers were applied @ 10: 8: 8 g m⁻² of nitrogen, phosphorus and potassium. Half quantity of nitrogen and full phosphorus and potassium was applied before transplanting while the remaining half dose of nitrogen was applied after one month transplanting. The observations on plant height (cm), plant spread (cm), stem diameter (cm), stalk length (cm), number of primary branches/plant, fresh weight of plant (g), dry weight of plant (g), days taken to first flower bud, days taken to first flower opening, duration of flowering(days), number of buds per plant, number of flowers per plant, flower diameter (cm), fresh weight of

flower (g), dry weight of flower (g), flower yield/plant (g) were recorded. The data obtained on various characters were subjected to multivariate hierarchical analytic, association and biplot graphical tools.

RESULTS AND DISCUSSION

1. First year of study (2018-19)

Divergence of traits. Significant variation observed among the genotypes for all the important traits as elucidated in Radar charts (Joshi *et al.*, 2010). Pusa Sona and Golden splendor showed maximum difference of plant height. Pin Pong Yellow showed maximum values for plant spread while minimum obtained by Pink Cloud (Fig. 1a). Orange Dazzle achieved minimum value for days taken to first flower bud while more by Bicolor Aruba. Earlier days of flowering seen for Pusa Aditya and Star Yellow took large number of days. Maximum number of flowers was for Pusa Sona whereas Orange dazzle had only minimum flowers among all the genotypes. Minimum number of days taken for first flower opening by Pusa Sona while maximum days showed by Pusa Splendar. Red Bolaro exhibited flowers of lest weight and flowers of more weight achieved by Pusa Guldata (Fig. 1b). Similar behavior of both genotypes was also observed for dry weight of plants.

Description of important morphological traits.

Plant height (cm)	Plant spread (cm)	Stem diameter (cm)	Stalk length (cm)	Number of primary branches/plant	Fresh weight of plant (g)	Dry weight of plant (g)	Days taken to first flower bud	Days taken to first flower opening	Duration of flowering (days)	Number of buds per plant	Number of flowers per plant	Flower diameter (cm)	Fresh weight of flower (g)	Dry weight of flower (g)	Flower yield/plant (g)
PH	PS	SD	SL	PB	PFW	PDW	DFBD	DFLR	DUF	NB	NFF	FD	FWT	DWT	FYP

Details of genotypes considered for the study.

Pusona	Staryllo	Pusacntr	Thichq	Pguldata	Strwhite	Pushwt	Pusadity	Tatacntr	Pchitrksh	Whitgdgt	Biclarba	Pingpylo	Redborlo	Orngedz
Pusa Sona	Star Yellow	Pusa Centnary	Thichn Queen	Pusa Guldata	Star White	Pusa Shwet	Pusa Aditya	Tata Century	Pusa Chitrksha	White Gadget	Bicolor Aruba	Pin Pong Yellow	Red Borolo	Orange Dazzle
Pinksens	Potnzapi	Prpllima	Papyaclv	Greenbtn	Clscbeut	Biscutpr	Pinkclou	Hldghti	Hydc	Brightyl	Rglmour	Myur	Goldnspl	Grdbeuty
Pink Sensation	Potenza Pink	Purple Lima	Papaya Clever	Green Button Lorenzo	Classic Beauty	Biscuit Parcel	Pink Cloud	Haldighati	HYDC12	Bright Yellow	Red Glamour	Mayur	Golden Splendour	Garden Beauty

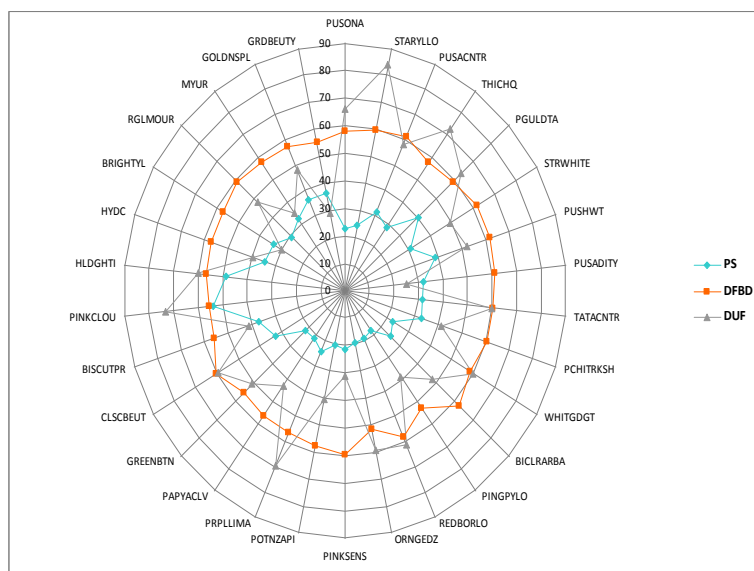


Fig. 1a. Radar chart to depict the divergence in traits (2018-19).

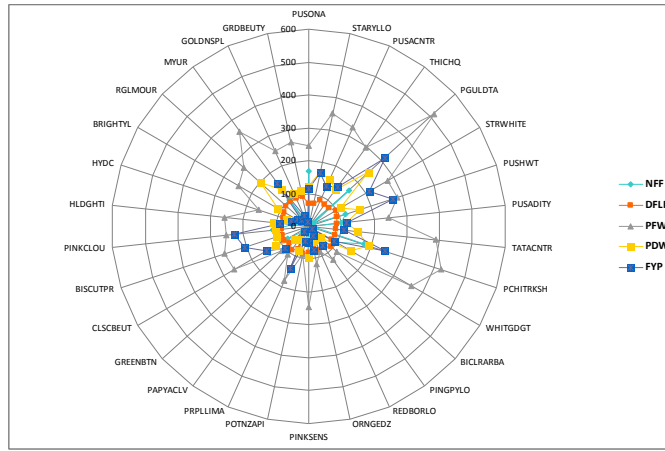


Fig. 1b. Radar chart to explore the divergence in traits (2018-19).

Table 1: Loadings of traits as per Principal components (2018-19).

Traits	PC1	PC2
Plant height	0.0441	0.3486
Plant spread	0.2699	0.1284
Stem diameter	0.0000	0.0859
Stalk length	-0.2681	0.1620
Number of primary branches/plant	0.2389	-0.0617
Fresh weight of plant	0.3571	0.2540
Dry weight of plant	0.3446	0.2465
Days taken to first flower bud	0.1658	0.2393
Days taken to first flower opening	0.0423	0.1454
Duration of flowering	0.0479	0.2236
Number of buds per plant	0.4156	-0.1518
Number of flowers per plant	0.4119	-0.1570
Flower diameter	-0.0980	0.4629
Fresh weight of flower	-0.1378	0.4253
Dry weight of flower	-0.1905	0.3002
Flower yield/plant	0.3333	0.1946
Per cent variation	30.05	20.82

More flower yield per plant expressed by Pusa Guldata followed by Pusa Shwet, Pusa Chitrksha whereas low yielders were Bicolor Aruba, Garden Beauty, Papaya Clever etc. These variations in growth and flower characters may be attributed to genetic makeup of genotypes (Singh *et al.*, 2017; Negi *et al.*, 2019).

Association analysis. A matrix of simple correlation coefficients between the selected traits were computed and presented in Table 2. Mostly significant positive correlation coefficient values had observed of flower yield per plant trait with number of flowers per plant, number of buds per plant, fresh weight of plant, dry weight of plant, plant spread whereas negative correlations of low magnitude were seen with stalk length, stem diameter, dry weight of flower (Uddin *et al.*, 2015; Negi *et al.*, 2015). Direct correlation of dry weight of flower observed with flower diameter, duration of flowering, stalk length, plant height and indirect with number of flowers per plant, number of buds per plant, number of primary branches per plant, days taken to first flower opening trait. Trait number of flowers per plant expressed positive perfect correlation value with number of buds per plant and positive with fresh weight of plant, dry weight of plant, number of primary branches/plant, plant spread along with negative for stalk length.

Number of buds per plant expressed positive relationship with number of primary branches/plant, fresh weight of plant, dry weight of plant, plant spread as well negative with stalk length. Only weak correlation exhibited by duration of flowering except of moderate with days taken to first flower opening. Positive relationship of plant spread with plant height, number of primary branches per plant with plant spread, fresh weight of plant with plant spread, dry weight of plant with fresh weight of plant and plant spread, days taken to first flower bud with fresh weight of plant & dry weight of plant, days taken to first flower opening with plant spread & days taken to first flower bud also observed (Prabhu *et al.*, 2018). However, the negative values of association ships were fresh weight of plant with stalk length, duration of flowering with days taken to first flower opening & stem diameter, number of buds per plant with stalk length, days taken to first flower opening & plant height, flower diameter with number of flowers per plant, number of buds per plant, number of primary branches/plant, fresh weight of flower with plant spread, stem diameter, number of primary branches per plant, days taken to first flower opening, number of buds per plant & number of flowers per plant, dry weight of flower with plant spread, stem diameter, flower diameter, days taken to first flower opening, number of buds per plant & number of flowers

per plant, dry weight of flower with plant spread, stem diameter, number of primary branches/plant, fresh weight of plant, days taken to first flower opening, number of buds per plant & number of flowers per plant, lastly of flower yield per plant with stem diameter, stalk length, days taken to first flower opening & dry weight of flower (Baskaran *et al.*, 2016).

Multivariate Hierarchical clustering. Using a univariate statistical analysis and standard deviations for each one of trait does not provide a complete insight into the complex analysis (Reddy *et al.*, 2016). Multivariate statistical methods are appropriate tools for the analysis of the complex structure. The hierarchical

cluster analysis is a simple way of grouping the set of selected genotypes as per their similarities based on 15 morphological variables. Four clusters of genotypes had been observed four, twelve, five, nine amounts to 13.3, 40, 16.7 and 30 percent of total genotypes (Fig. 2).

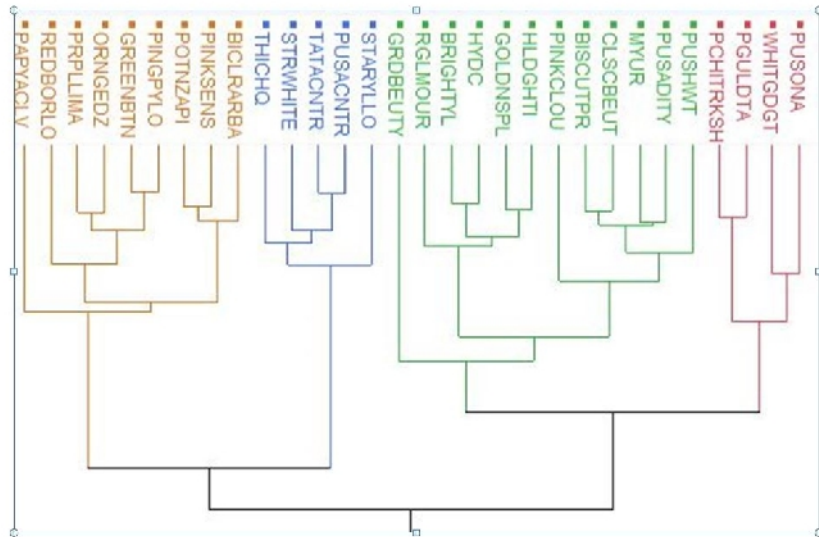


Fig. 2. Multivariate hierarchical clustering of genotypes by Ward's method (2018-19).

Table 2: Association analysis among important morphological traits (2018-19).

	PS	SD	SL	PB	PFW	PDW	DFBD	DFLR	DUF	NB	NFF	FD	FWT	DWT	FYP
PH	0.4536	-0.0801	0.1381	0.0913	0.2966	0.2801	0.2689	-0.3047	0.1636	-0.1939	-0.1848	0.3723	0.3043	0.1903	0.1927
PS		0.2298	-0.0864	0.4492	0.4600	0.4077	0.1129	0.4493	0.0553	0.3718	0.3676	0.0765	-0.1834	-0.3013	0.4536
SD			0.1668	0.1010	0.1140	0.1327	0.0095	0.3303	-0.2005	-0.0918	-0.0892	0.3476	-0.0597	-0.0858	-0.1383
SL				-0.1633	-0.4454	-0.3790	-0.0951	0.1525	0.1068	-0.6124	-0.6053	0.3291	0.3648	0.1298	-0.1794
PB					0.2693	0.1954	0.0283	0.0368	0.1081	0.4406	0.4122	-0.1617	-0.2845	-0.3242	0.2891
PFW						0.9305	0.4287	0.1444	0.2044	0.5436	0.5293	0.2117	0.1820	-0.0872	0.6501
PDW							0.4627	0.1715	0.2301	0.5268	0.5148	0.1671	0.1321	-0.0894	0.6033
DFBD								0.3601	0.0239	0.2192	0.2228	0.3306	0.0769	0.0395	0.2870
DFLR									-0.4732	-0.1173	-0.1031	0.2935	-0.2243	-0.0231	-0.0132
DUF										0.0671	0.0364	0.1470	0.5178	0.2557	0.3552
NB											0.9971	-0.3995	-0.4252	-0.4190	0.6686
NFF												-0.4022	-0.4454	-0.4229	0.6604
FD													0.6685	0.5539	0.1148
FWT														0.5686	0.2178
DWT															-0.0457

Biplot analysis. Principal component analysis simplifies the complex data by transforming number of correlated variables into a smaller number of variables called principal components. The first principal component accounts for maximum variability in the data as compared to each succeeding component (Geleta, 2020). Scatter diagram was plotted to show the variation pattern. Mean value of each variable were standardized prior to cluster and principal component analysis to avoid the effects due to difference in scale. Results of the principal component analysis (PCA) indicated that the first two components were important in explaining the variation among the 30 studied genotypes and cumulatively accounted for 50.9% of the total phenotypic variation (Table 3).

The first principal component (PC) accounted for 30.1% of the total variation. It illustrated the variations in number of buds per plant, number of flowers per plant, fresh weight of plant, dry weight of plant, flower yield per plant and plant spread. Principal component two contributed 20.9% to the total variation. Six variables, flower diameter, fresh weight of flower, plant height, dry weight of flower, fresh weight of plant were to contribute more to second PC. Out of the 16 traits evaluated, 08 were found to contribute most to the first two principal components (Table 3) and were therefore considered important to discriminate. The biplot analysis is an appropriate method to analyse interaction between genotypes and traits and narrowing down the number of traits to the ones contributing a

major portion to the variability. The difference between the biplot origin and genotype position in the biplot is the vector length of the genotype and it is a measure of the distinctiveness of the genotype from other genotypes as reviewed by Pawar *et al.*, (2020). In the biplot vectors of traits showing acute angles are positively correlated whereas those showing obtuse or straight angles are negatively correlated and those with right angles have no correlation. The high positive correlation has been observed between number of buds per plant, number of flowers per plant, number of primary branches per plant at the same time among of plant spread, days taken to first flower bud, flower yield/plant, dry weight of plant, fresh weight of plant

traits in other quadrant as well as among stalk length, dry weight of flower, fresh weight of flower traits (Fig. 3). Right angles also observed of plant height, duration of flowering, days taken to first flower bud traits with number of primary branches/plant, number of buds per plant, number of flowers per plant. Straight line angle of stalk length with number of flowers per plant showed no relationship. The genotypes having long length of the vector have higher or extreme values for one or more characters Pusa Guldata, Pusa Chitkarsh, Pusa Sona, Pin Pong Yellow. Selection among such genotypes may be performed either for further trials or for their use as parents in breeding programs.

Table 3: Loadings of traits as per Principal components (2019-20).

Traits	PC1	PC2
Plant height	0.0229	0.3399
Plant spread	0.2640	0.1973
Stem diameter	0.0202	0.1197
Stalk length	-0.3142	0.1438
Number of primary branches/plant	0.2431	-0.0100
Fresh weight of plant	0.3258	0.2925
Dry weight of plant	0.3311	0.2770
Days taken to first flower bud	0.0486	0.1392
Days taken to first flower opening	0.0338	0.1576
Duration of flowering	0.0170	0.2244
Number of buds per plant	0.4272	-0.0856
Number of flowers per plant	0.4236	-0.0912
Flower diameter	-0.1424	0.4002
Fresh weight of flower	-0.1923	0.3951
Dry weight of flower	-0.2146	0.3952
Flower yield/plant	0.2947	0.2559
Per cent variation	29.76	23.17

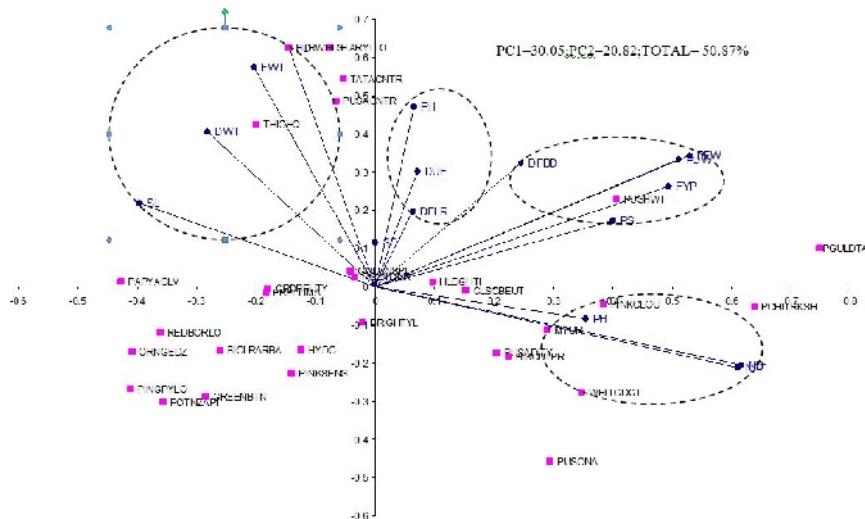


Fig. 3. Biplot analysis of genotypes and traits based on principal components (2018-19).

2. Second year of study (2019-20)

Divergence of traits. Golden splendor and Pusa Sona showed maximum difference of values for plant height. Pink Cloud showed maximum values for plant spread while minimum obtained by Pin Pong Yellow (Fig. 4a). Orange Dazzle achieved minimum value for days taken to first flower bud while more days by Star white. Earlier days of flowering seen for Pusa Aditya while large number of days by Star Yellow. Maximum numbers of flowers were for PUSA Chitrksha whereas

Star Yellow had only minimum flower among all the genotypes. Minimum days taken for first flower of opening by Pusa Sona genotype while maximum days showed by Star White. Least weight of fresh plant exhibited by Potenza Pink and of more weight by Pusa Guldata (Fig. 4b). Red Borolo and Pusa Guldata selected for dry weight of plants. More flower yield per plant expressed by Pusa Shwet followed by Pusa Guldata, Pusa Chitrksha whereas low yielders were Bicolor Aruba, Garden Beauty, Papaya Clever etc.



Fig. 4a: Radar chart to depict the divergence in traits (2019-20).

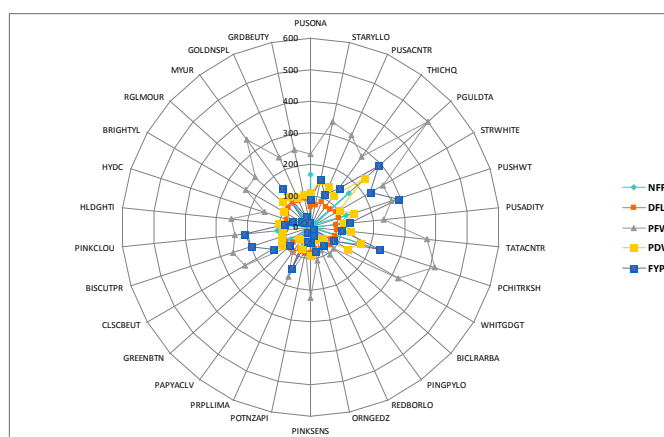


Fig. 4b: Radar chart to explore the divergence in traits (2019-20).

Association analysis. Significant positive correlation coefficient values had been observed for flower yield/plant with traits number of buds per plant, dry weight of plant, fresh weight of plant, number of flowers per plant, plant spread whereas weak negative correlations were seen with stalk length, stem diameter (Table 4). Direct correlation of dry weight of flower observed with fresh weight of flower, flower diameter, duration of flowering, stalk length, plant height while indirect with number of flowers per plant, number of buds per plant, number of primary branches per plant, days taken to first flower opening. Direct relations of fresh weight of flower exhibited with flower diameter, duration of flowering, stalk length, plant height along with indirect of number of flowers per plant, number of buds per plant, number of primary branches per plant and plant spread traits. Positive values observed for flower diameter with stem diameter, plant height, stalk length, days taken to first flower opening at the same time negative values evident with number of flowers per plant, number of buds per plant & number of primary branches per plant, plant spread. Positive perfect correlation of number of flowers per plant with number of buds per plant and significant positive with dry weight of plant, fresh weight of plant, number of

primary branches per plant, plant spread while indirect for stalk length, plant height & days taken to first flower opening. Similar behavior of number of buds per plant was observed as direct with dry weight of plant, fresh weight of plant, number of primary branches per plant, Plant spread and indirect with stalk length, plant height, days taken to first flower opening. Significant direct association had been expressed by duration of flowering with dry weight of plant and indirect with days taken to first flower opening traits. All positive values maintained by days taken to first flower opening while more magnitude with plant spread, days taken to first flower bud, plant height, stem diameter only. Negative correlation of very weak magnitude was expressed by days taken to first flower bud with stem diameter, number of primary branches per plant, stalk length traits. All direct relations with traits were exhibited by dry weight of plant except with stalk length. Trait fresh weight of plant also showed indirect with stalk length only. Significant direct with plant spread, number of buds per plant, number of flowers per plant, fresh weight of plant, flower yield per plant traits observed for number of primary branches per plant. Both types of correlations portrayed by stalk length while majority were of negative values.

Table 4: Association analysis among important morphological traits (2019-20).

	PS	SD	SL	PB	PFW	PDW	DFBD	DFLR	DUF	NB	NFF	FD	FWT	DWT	FYP
PH	0.4580	-0.0040	0.1168	0.0937	0.3270	0.3029	0.5675	0.3571	0.1844	-0.1899	-0.1855	0.3741	0.2886	0.2801	0.1978
PS		0.2671	-0.1426	0.4389	0.4950	0.4491	0.3224	0.4168	0.0784	0.3491	0.3409	0.1349	-0.1376	-0.2131	0.4684
SD			0.1442	0.2025	0.1641	0.1964	-0.1358	0.2896	-0.1338	-0.0569	-0.0468	0.4015	-0.0045	0.0031	-0.0567
SL				-0.2034	-0.4492	-0.4304	-0.0077	0.1344	0.1383	-0.6437	-0.6354	0.3491	0.4263	0.4474	-0.1567
PB					0.2637	0.2236	-0.1095	0.0016	0.1142	0.4262	0.3971	-0.1231	-0.2816	-0.3217	0.2742
PFW						0.9611	0.1090	0.1897	0.1919	0.5481	0.5295	0.2184	0.1743	0.1432	0.6201
PDW							0.1072	0.1729	0.2360	0.5783	0.5606	0.1491	0.1414	0.1156	0.6346
DFBD								0.4068	-0.1374	-0.0273	0.0081	0.0786	-0.0670	0.0073	0.1264
DFLR									-0.3682	-0.1281	-0.1187	0.3540	-0.1638	-0.0661	0.0750
DUF										0.0553	0.0379	0.0903	0.4918	0.4418	0.3338
NB											0.9962	-0.4138	-0.4209	-0.4619	0.6399
NFF												-0.4177	-0.4384	-0.4739	0.6320
FD													0.6415	0.6981	0.1379
FWT														0.9568	0.2305
DWT															0.1771

Multivariate hierarchical clustering. Multivariate hierarchical method had been utilized to understand the clustering mechanism of genotypes based on studied traits simultaneously. Clustering was used to study the genetic diversity and identification of cultivars of

chrysanthemum genotypes on the basis of morphological characters. Four clusters of genotypes had been seen in figure with eleven, five, ten, five genotypes respectively amounted to 36.7, 16.7, 33.3 and 16.7 percent of total genotypes (Fig. 5).

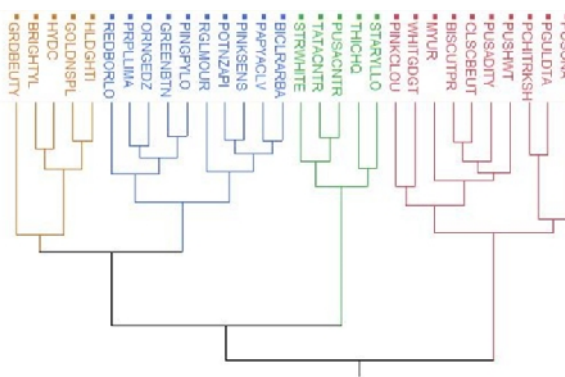


Fig. 5. Multivariate hierarchical clustering of genotypes by Ward's method (2019-20).

Biplot analysis. First two principal components totaled about 52.9% of the phenotypic variation (Table 3). The first principal component (PC) contributed about 29.8% of the total variation and major traits were number of buds per plant, number of flowers per plant, dry weight of plant, fresh weight of plant, stalk length, flower yield per plant. Principal component two contributed 23.2% to the total variation. Variables viz., flower diameter, dry weight of flower, fresh weight of flower, plant height, fresh weight of plant and dry

weight of plant contributed more for second component. The high positive correlation has been observed between number of buds per plant, number of flowers per plant, number of primary branches per plant at the same time among of plant spread, flower yield per plant, fresh weight of plant, dry weight of plant traits in other quadrant as well as among stalk length, dry weight of flower, fresh weight of flower, days taken to first flower bud traits (Fig. 6).

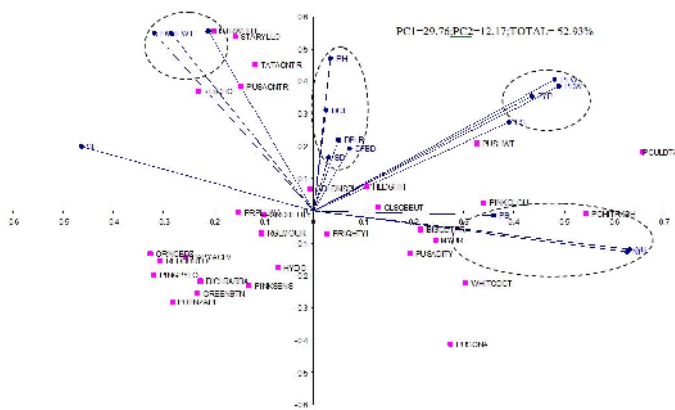


Fig. 6. Biplot analysis of genotypes and traits based on principal components (2019-20).

Right angles also observed of plant height, duration of flowering, days taken to first flower bud traits with number of primary branches/plant, number of buds per plant, number of flowers per plant. Straight line angle of stalk length with number of flowers per plant showed absence of any relationship.

Conflict of Interest. None.

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