Journal of Crop and Weed, 18(2): 207-215 (2022)
ISSN- O : 2349 9400 ; P : 0974 6315

http://cwssbckv.org
www.cropandweed.com

Evaluation of tuberose (*Polianthes tuberosa* L.) diversity using multivariate analysis

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Received : 27.04.2022 ; Revised : 16.06.2022 ; Accepted : 26.06.2022

DOI: https://doi.org/10.22271/09746315.2022.v18.i2.1591

ABSTRACT

Eighteen treatment combinations were evaluated at CCS Haryana Agricultural University, Hisar during 2019 and 2020 cropping seasons to study the diversity in tuberose traits by multivariate analysis. Significant differences had been observed by analysis of variance for all the traits during both years. Plant height varied from 40.2 to 82.2 cm, while number of leaves ranged 21.2 to 52.4. Spike length expressed deviation of 33 to 80.2 cm and rachis length showed 15.6 to 42.2 cm. Bulbs yield per clump ranged 154 to 860g with Acid (17.5 to 20.5) and Ester values from 220.3 to 236.7 for the first year. Second year of study observed plant height varied from 45.3 to 85.2 cm and number of leaves expressed from 38.2 to 78.4 while spike length showed variation from 38.3 to 81.1cm. The rachis length showed 18.3 to 41.3 cm along with variation of 34.6 to 67.4g for spike weight. Bulbs yield per clump showed variation from 191.9 to 1044.4g and Acid (17.7 to 20.6) along with Ester values expressed variation 220.3 to 236.7. Biplot analysis showed first two principal components accounted for 91.6 % and 89.1 % of the total variation for years. Four clusters of traits were evident in respective analysis as two clusters in first quadrant and remaining two clusters in second quadrant. Two dimensional clustering under hierarchical multivariate showed plant height associated with spike length, rachis length grouped and maintained distance from group of Ester value, pH of oil, number of leaves. Highly significant direct correlation had been maintained by physical and chemical traits for considered treatment combinations as chemical traits would be enhanced with additional positive augmentation of physical traits.

Keywords *:* Biplot analysis, correlation analysis, hierarchical multivariate clustering, *Polianthes tuberose*,

Tuberose (*Polianthes tuberosa* L.) possessed vast potential of uses *viz*. cut flower trade, long vase life, along with essential aromatic components for oil industry in the world market (Kumar *et al.,* 2021). Tuberose flowers out of many popular flowers have been appreciated much for their aesthetic, attractive and elegant beauty and pleasant fragrance besides their wide adaptability to varied climate and soil conditions (Khan *et al.,* 2020). Tuberose is cultivated on large scale in France, South Africa, North Carolina, USA and India at world level (Dogra *et al.,* 2020). Major tuberose growing states in India are Karnataka, West Bengal, Maharashtra, Andhra Pradesh and Tamil Nadu. White flowers are highly fragrant and rich in benzyl achohol, eugenol, benzyl benzoate and methyl anthranilate. Medicinal and aromatic properties of essential oil extracted from flowers has been mentioned in literature (Zamin *et al.,* 2020). The valuable aromatic oil of tuberose flowers have great demand in the high cost perfume industry (Qureshi *et al.,* 2018). More over, the essential oil is exported to foreign countries like France, Italy and other countries at attractive prices. Flowers need to be harvested at appropriate stages to ensure higher oil content with better quality in tough export scenario (Madhumathi *et al.,* 2018). Staggered planting has been established as important strategy to ensure continuous supply of quality flowers to the market (Meena *et al.,* 2018). The vagaries of temperature, humidity and rainfall pattern affected the harvest yield of flowers which forced to plan cultivation of crops over the different times of sowing in the fields (Jadhav *et al.,* 2020). The planned staggering planting over different dates enables a continuous supply of cut flowers over an extended period to harvest flowers and helps to avoid glut in the market. This strategy would provide regular income to growers, employment to youth and increased availability of flowers to the users. Hierarchical multivariate analysis based on eighteen treatments combinations had been evaluated to study diversity in morphological and chemical characters.

MATERIALS AND METHODS

Genotypes performance had varied from one date of sowing to other dates owing to varying climatic conditions of the country over the time period. Eighteen treatment combinations of experiment consisted of six promising genotypes sown at three dates of sowings at Experimental Farm of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2018-19 and 2019-20 cropping seasons to study diversity in morphological and chemical characters. Factorial experiment in random complete block designs with three replications was laid out in fields. Net plot size of 1.5m x 1.5m was laid out with plant to plant spacing of 30 cm

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x 30cm to accommodate twenty five plants per plot. The recommended agronomical practices were adopted to raise the crop. Data pertaining to various traits *viz*., plant height (cm), number of leaves per plant, spike length (cm), rachis length (cm), spike weight (g), number of florets per spike, number of bulbs, weight of bulbs (g), bulbs yield per clump(gm), pH of oil, Acid and Ester values were observed. Statistical analysis and graphical presentations of research data were carried out by SAS version 9.3 along with JMP 9 software's .

RESULTS AND DISCUSSION

Descriptive analysis

First year of study

Highly significant difference had been observed by analysis of variance for all the traits. Plant height considered to be a good index of plant vigor contributed towards higher productivity. Variation from 40.2 to 82.2 cm was observed among treatments (Ali *et al.,* 2019). The variation in number of leaves ranged from 21.2 to 52.4 which might be due to variation in amount of stored food material in mother corms expressed by their sizes (Table 1). It could also be due to variation in rate of vegetative growth among the genotypes that could be attributed to their genetic makeup and could have been further influenced by the date of sowings (Ramachandrudu and Thangam, 2016). Variation from 33 to 80.2 cm in spike length and rachis length (15.6 to 42.2 cm) might be due to the inherent capacity of the particular genotype as well as the sowing dates during the growing period. The increase in spike and rachis length might be because of cell division, cell elongation and longer days during spike/ rachis formation stage, which increases synthesis of amino acids, chlorophyll formation and better carbohydrate transformation, which resulted into better rachis length and ultimately produced more florets per spike. This might also be due to the fact that long days caused better plant vegetative growth and stimulated the auxiliary buds resulting in more rachis length. The numbers of florets per spike directly influence the yield of the genotype as varied from 16.2 to 30. Good margin for number of bulbs had been observed as 8.8 to 28.5 among the treatments. The increased yield might be due to its capacity to produce maximum number of bulbs which is a genetic makeup of the genotype. Bulb weight (15.2 to 30.1g) is desirable important character for marketing of tuberose as such as loose flowers for garland making. Bulbs yield per clump ranged from 154 to 860g to highlight the scope for cultivation of particular genotypes as per suitable date of sowing (Naik *et al.,* 2018). Acid (17.5 to 20.5) and Ester variation (220.3 to 236.7) may be one of the reasons for the variation in essential oil contents among treatments. Little range wasachieved by pH value of oil (4.5 to 5.6) for the considered treatments.

Second year of study

Plant height varied from 45.3 to 85.2 cm among treatments (Table 2). Number of leaves expressed difference from 38.2 to 78.4 while spike length managed variation from 38.3 to 81.1cm. The rachis length showed (18.3 to 41.3 cm) along with variation of 34.6 to 67.4 for spike weight. The numbers of florets per spike though influence the yield of the genotype varied from 18.4 to 31.6. Number of bulbs managed 9.7 to 32.5 among the treatments. More Bulb weight is desirable for marketing of tuberose exhibited (17.5 to 32.1g) whereas bulbs yield per clump showed variation from 191.9 to 1044.4g to highlight the scope for large scale cultivation of particular genotypes as per suitable date of sowing. pH of oil value managed only small deviation as range achieved by 4.6 to 5.5 (Meena *et al.,* 2018). Acid (17.7 to 20.6) and Ester variation (220.3 to 236.7) may be one of the reasons for variation in essential oil contents among treatments.

Biplot clustering analysis

First year of study

First two principal components were important in explaining 91.6 % of the total variation among physical and chemical traits (Table 3). First component (PC) accounted for 84.2% of the total variation. It illustrated that variations in pH of oil, number of bulbs, spike weight, Number of florets per spike, bulbs yield per clump, Ester value, spike length contributed more. Second Principal component augmented by 7.3% to the remaining variation traits plant height, spike length, rachis length, weight of bulb, acid value, bulbs yield per clump were major contributors. Seven traits out of the evaluated 12 traits contributed most to the first two principal components (Table 3) and would able to discriminate the variations among the treatments. Direct high association of spike length was observed with plant height and rachis length (Fig. 1). Positive correlation has been observed between pH of oil with Ester values (Bharathi and Kirthishree, 2019). Spike weight expressed direct association with number of florets per spike as well as with number of bulbs. Positive association was also expressed by bulbs yield per clump with acid values and weight of bulb. No association of bulbs yield per clump with acid values and weight of bulb traits showed by spike length observed with plant height and rachis length in this study (Ahmad *et al.,* 2019). Treatments having long length of the vector *viz*. D3G5, D3G4, D3G3, D1G3, D2G1, D1G1 have higher or extreme values for one or more traits. Four clusters of traits were evident in Biplot graphical representation as two clusters

Table 1: Analysis of morphological and chemical traits 2019

Treatments	Plant height (cm)	Number of leaves	Spike length (cm)	Rachis length (cm)	Spike weight (g)	Number of florets per spike	Number of bulbs	Weight of bulb (g)	Bulbs yield per clump (g)	pH of oil	Acid value	Ester value
D1G1	40.27	21.20	33.00	15.60	25.13	16.40	8.87	17.43	154.99	4.58	17.66	222.23
D1G2	51.53	27.80	44.53	19.53	35.57	16.20	14.13	15.27	216.23	4.84	17.59	220.36
D1G3	71.13	43.07	66.13	26.13	48.33	24.60	23.60	26.80	632.28	5.43	20.08	236.27
D1G4	74.60	31.53	69.60	29.60	41.87	23.67	18.80	21.57	405.47	5.24	19.22	234.24
D1G5	73.53	40.40	66.53	28.53	36.30	19.27	16.93	19.47	329.26	5.05	18.03	229.40
D1G6	67.00	35.40	61.60	21.60	33.43	21.60	14.60	18.07	263.85	5.14	18.64	230.23
D2G1	43.20	24.47	38.20	18.20	29.83	18.00	11.60	19.93	231.16	4.71	17.78	222.42
D2G2	54.07	32.00	48.47	23.47	38.60	18.40	15.93	16.73	266.78	4.95	17.65	221.09
D2G3	74.80	47.00	72.40	32.33	54.80	27.27	25.60	28.40	727.33	5.49	20.40	236.41
D2G4	78.60	36.33	75.60	36.60	44.43	25.67	21.07	23.73	500.12	5.31	19.39	234.39
D2G5	76.13	41.87	71.13	34.13	39.40	21.07	18.33	20.57	377.23	5.11	18.11	229.65
D2G6	68.60	37.73	64.60	25.60	35.37	23.60	15.40	20.23	311.35	5.19	18.74	230.53
D3G1	46.13	28.07	43.13	23.13	32.47	20.33	12.93	21.17	273.73	4.78	17.85	222.67
D3G2	56.80	36.20	53.80	28.80	41.53	21.27	17.93	18.67	334.90	5.04	17.75	221.32
D3G3	78.47	52.40	76.47	39.20	58.63	30.00	28.53	30.13	860.03	5.55	20.49	236.67
D3G4	82.20	39.27	80.20	42.20	46.40	27.07	22.40	25.90	580.21	5.36	19.48	234.59
D3G5	78.67	44.13	75.67	39.67	42.73	23.27	19.80	22.10	437.46	5.16	18.22	229.80
D3G6	73.13	39.60	70.13	30.13	38.43	25.40	17.40	21.53	374.73	5.25	18.81	230.61
MSe	0.485	0.613	0.623	0.656	0.877	0.547	0.309	0.468	340.454	0.002	0.001	0.003
CD at 5%	1.156	1.299	1.310	1.344	1.554	1.227	0.922	1.136	30.617	0.065	0.061	0.084

Table 2: Analysis of morphological and chemical traits 2020

Treatments	Plant height (cm)	Number of leaves	Spike length (cm)	Rachis length (cm)	Spike weight (g)	Number of florets per spike	Number of bulbs	Weight of bulb (g)	Bulbs yield per clump (g)	pH of oil	Acid value	Ester value
D1G1	45.37	51.73	38.37	18.37	34.60	18.40	9.73	19.90	193.93	4.65	17.72	222.23
D1G2	58.93	38.20	51.73	28.27	42.77	18.87	14.80	17.50	259.29	4.87	17.64	220.36
D1G3	79.93	73.67	74.93	32.60	61.27	26.27	27.67	28.10	777.14	5.45	20.57	236.27
D1G4	76.67	58.67	69.67	29.47	45.47	24.60	19.53	25.37	495.98	5.26	19.31	234.24
D1G5	80.60	44.53	67.53	28.53	43.70	21.73	17.67	23.23	410.50	5.07	18.08	229.40
D1G6	76.73	49.07	65.33	25.33	40.47	21.73	15.73	19.77	310.79	5.18	18.70	230.23
D2G1	49.07	54.13	43.07	22.60	37.47	20.13	12.33	20.83	256.99	4.74	17.83	222.42
D2G2	61.53	40.80	55.53	33.53	45.43	20.53	16.33	18.97	309.64	4.97	17.69	221.09
D2G3	82.40	75.53	77.60	37.60	64.43	29.40	30.40	30.10	915.42	5.52	20.67	236.41
D2G4	79.73	61.80	77.27	35.47	47.63	26.60	22.13	27.50	608.88	5.35	19.43	234.39
D2G5	83.27	69.60	73.53	33.80	46.10	23.33	18.73	24.80	464.43	5.14	18.16	229.65
D2G6	79.73	52.20	69.13	30.13	42.47	23.53	16.67	21.20	353.10	5.24	18.79	230.53
D3G1	52.53	56.07	47.53	26.53	40.50	21.87	13.47	23.00	309.58	4.80	17.89	222.67
D3G2	64.47	42.53	59.47	36.27	48.17	22.00	18.67	19.83	370.18	5.05	17.80	221.32
D3G3	85.13	78.07	81.13	41.33	67.43	31.67	32.53	32.09	1044.44	5.58	20.75	236.67
D3G4	82.60	64.13	80.27	41.20	49.50	28.60	23.40	30.03	702.67	5.40	19.56	234.59
D3G5	85.27	78.40	78.20	39.47	48.33	24.73	20.33	27.53	559.73	5.18	18.38	229.80
D3G6	82.53	59.60	72.73	34.87	45.10	26.20	18.07	22.73	410.83	5.28	18.86	230.61
MSe	0.4023	1.4653	0.6723	0.8767	0.7141	0.7477	0.3478	0.3135	379.31	0.0001	0.0005	0.0015
CD at 5%	1.052	2.009	1.361	1.554	1.402	1.435	0.979	0.929	32.317	0.020	0.037	0.064

Table 3: Loading of traits for tuberose genotypes in 2019

Trait	Principal Component-1	Principal Component -2	Trait	Principal Component-1	Principal Component-2
Plant height	0.2783	0.4665	Number of bulbs	0.3030	-0.1091
Number of leaves	0.2827	0.1513	Weight of bulb	0.2815	-0.3774
Spike length	0.2860	0.4293	Bulbs yield per clump	0.2978	-0.2965
Rachis length	0.2651	0.4005	pH of oil	0.3054	0.0259
Spike weight	0.2912	-0.1892	Acid value	0.2845	-0.3603
Number of florets per spike	0.2981	-0.0789	Ester value	0.2878	-0.0027

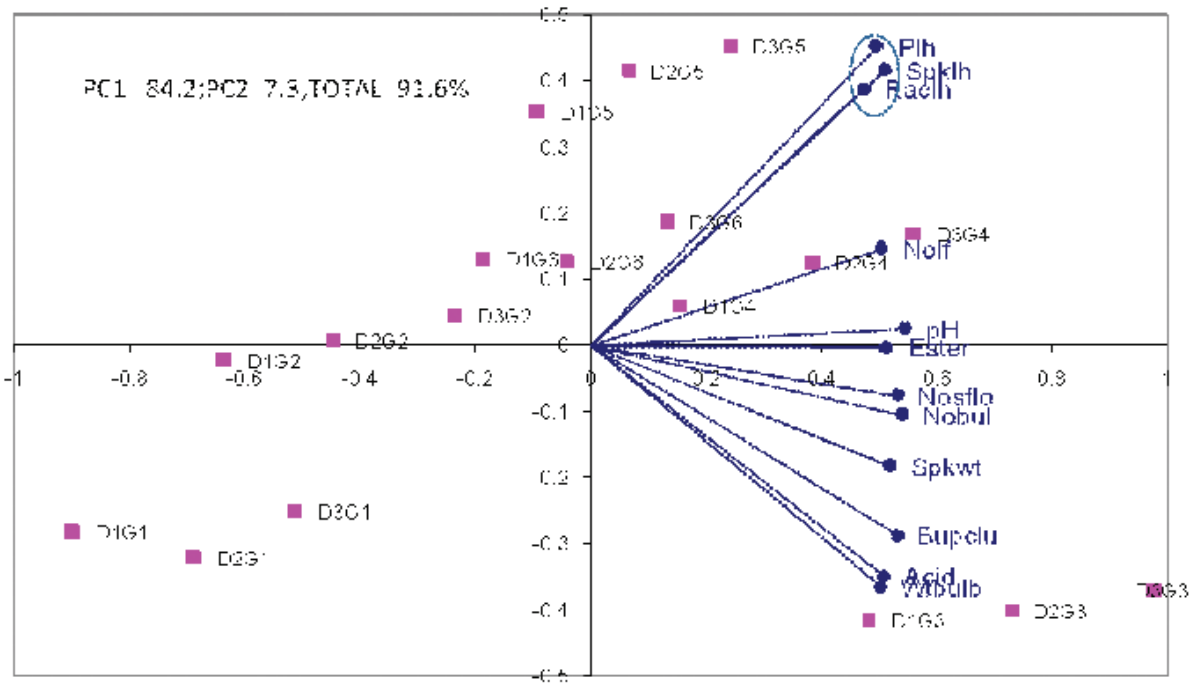

Fig. 1: Biplot graphical analysis of treatments and traits (2019)

D1G1	D1G2	D1G3	D1G4	D1G5	D1G6	D2G1	D2G2	D2G3	D2G4	D2G5	D2G6
D3G1	D3G2	D3G3	D3G4	D3G5	D3G6						
Plh	Nolf	Spklh	Raclh	Spkwt	Nosflo	Nobul	Wtbulb	Bupclu	pH	Acid	Ester
Plant height	Number of leaves	Spike length	Rachis length	Spike weight	Number of florets per spike	Number of bulbs	Weight of bulb	Bulbs yield per clump	pH of oil	Acid value	Ester value

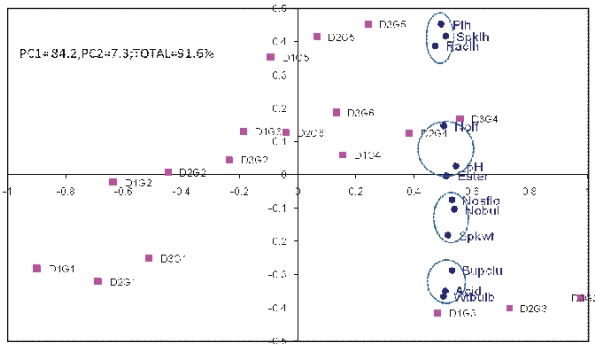

Fig. 2: Biplot clustering of traits (2019)

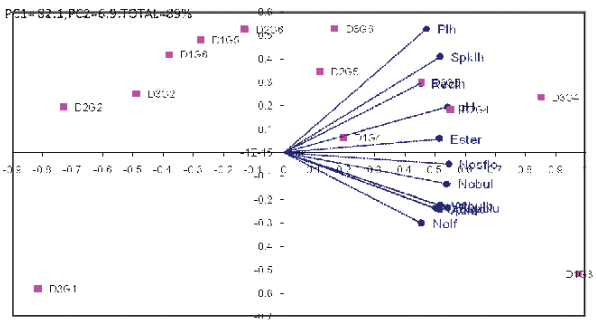

Fig. 3: Biplot graphical analysis of treatments and traits (2020)

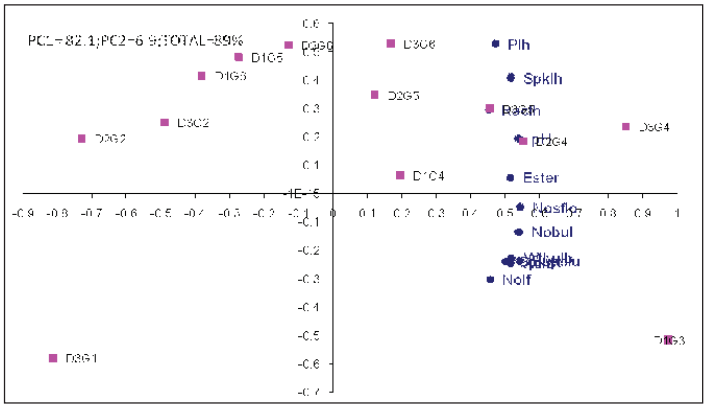

Fig. 4: Biplot clustering of traits (2020)

Table 4: Loading of traits for genotypes x date of sowing combinations in 2020

Trait	Principal Component-1	Principal Component -2	Trait	Principal Component-1	Principal Component-2
Plant height	0.2664	0.5538	Number of bulbs	0.3055	-0.1403
Number of leaves	0.2578	-0.3159	Weight of bulb	0.2935	-0.2375
Spike length	0.2917	0.4275	Bulbs yield per clump	0.3065	-0.2483
Rachis length	0.2556	0.3105	pH of oil	0.3057	0.2043
Spike weight	0.2836	-0.2514	Acid value	0.2922	-0.2559
Number of florets per spike	0.3082	-0.0505	Ester value	0.2907	0.0609

in first quadrant consisted of weight of bulb, Acid value, bulbs yield per clump and spike weight, number of bulbs, number of florets per spike (Fig. 2). Remaining two clusters in second quadrant comprised of Ester value, pH of oil, number of leaves, and plant height , spike length, rachis length.

Second year of study

Nearly 89.1 % of the total variation among traits was accounted by the first two principal components (Table 4). The first principal component (PC) accounted for 82.1% on the support of the variations in number of florets per spike, bulbs yield per clump, pH of oil, number of bulbs, Acid value, Ester value. 6.9% share of second principal component was augmented by the variation traits plant height, spike length, number of leaves, Acid value, spike weight. These 7 important traits were considered most discriminate to summarize variations among the treatments. Strong association of spike length was observed with plant height and rachis length. pH of oil maintained positive correlation with Ester values. Direct association of Number of florets per spike was observed with number of bulbs (Fig. 3). Spike weight was tightly associated bulbs yield per clump, acid values and weight of bulb. No association of spike length and plant height was assessed with number of florets per spike , acid values , weight of bulb traits in this second year of study. Treatments D3G1, D1G3, D2G2, D2G6, D3G6, D3G4 have extreme values for one or more traits as expressed by long length of the vector. Four clusters of traits were evident in Biplot graphical representation as two clusters in first quadrant consisted of number of leaves, weight of bulb, Acid value, bulbs yield per clump and number of bulbs, number of florets per spike (Fig. 4). Remaining two clusters in second quadrant were comprised of Ester value, pH of oil and plant height, spike length, rachis length.

Hierarchical Multivariate analysis

First year of study

Hierarchical multivariate clustering methods are appropriate to group the genotypes as per their similarities based on recorded traits (Ali *et al*., 2021). Ward's method was used for multivariate clustering of treatments based on studied traits. Only two clusters had been observed as marked by different colors in clustering pattern as well as by clustering handle (Fig. 5). Treatments (D1G1, D2G1, D3G1 & D1G2, D2G2, D3G2) were clustered in first and separated by cluster of remaining treatments. Two dimensional clustering had also been carried out to group the traits as per variations observed in studied treatments combinations during field evaluation (Fig. 6). Traits plant height ,spike length, rachis length were grouped and maintained distance from group consisted of Ester value, pH of oil, number of leaves .

Table 5: Association analysis among morphological and chemical traits in 2019

	Number of leaves	Spike length	Rachis length	Spike weight	Number of Florets per spike	Number of bulbs	Weight of bulb	Bulbs yield per clump	pH of oil	Acid value	Ester value
Plant height	0.832	0.995	0.866	0.714	0.795	0.790	0.628	0.701	0.885	0.689	0.867
Number of leaves		0.847	0.775	0.848	0.798	0.887	0.737	0.836	0.879	0.708	0.749
Spike length			0.897	0.745	0.841	0.816	0.672	0.735	0.902	0.712	0.869
Rachis length				0.755	0.791	0.800	0.679	0.734	0.757	0.573	0.682
Spike weight					0.844	0.989	0.849	0.960	0.896	0.839	0.738
Number of florets per spike						0.874	0.892	0.892	0.924	0.902	0.875
Number of bulbs							0.870	0.969	0.932	0.861	0.807
Weight of bulb								0.954	0.809	0.914	0.833
Bulbs yield per clump									0.887	0.916	0.823
pH of oil										0.901	0.908
Acid value											0.921

Table 6: Association analysis aong morphological and chemical traits in 2020

	Number of leaves	Spike length	Rachis length	Spike weight	Number of Florets per	Number of bulbs	Weight of bulb	Bulbs yield per clump	pH of oil	Acid value	Ester value
Plant height	0.587	0.975	0.730	0.605	0.759	0.717	0.668	0.678	0.889	0.655	0.840
Number of leaves		0.666	0.552	0.680	0.783	0.720	0.884	0.798	0.659	0.734	0.746
Spike length			0.825	0.704	0.856	0.814	0.778	0.787	0.941	0.742	0.875
Rachis length				0.740	0.796	0.784	0.692	0.747	0.775	0.553	0.550
Spike weight					0.838	0.977	0.784	0.947	0.828	0.854	0.690
Number of florets per spike						0.913	0.916	0.935	0.923	0.901	0.873
Number of bulbs							0.861	0.981	0.911	0.907	0.808
Weight of bulb								0.931	0.793	0.842	0.851
Bulbs yield per clump									0.875	0.918	0.829
pH of oil										0.899	0.916
Acid value											0.911

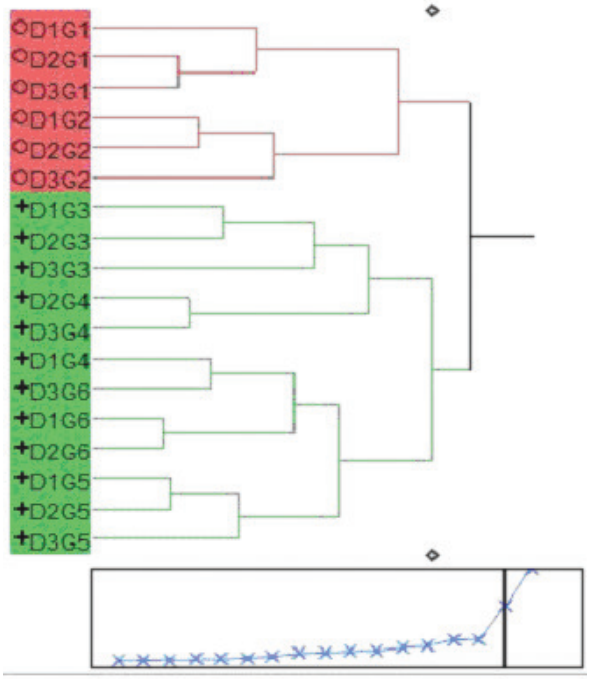

Fig. 5: Hierarchical Multivariate analysis of treatments by Ward's method in 2019

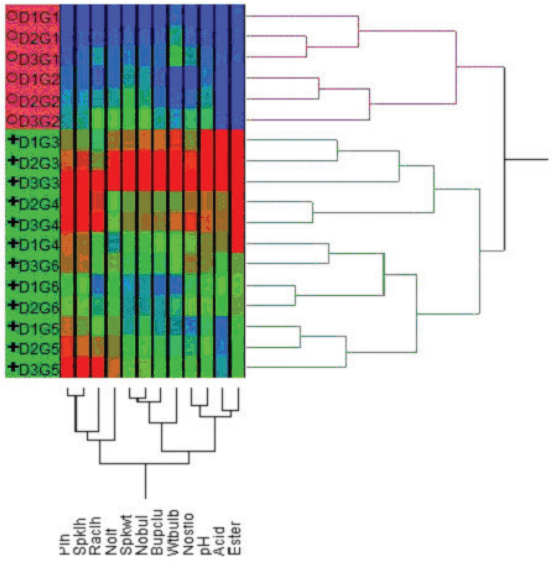

Fig. 6: Multivariate two clustering of treatments vis-à-vis traits in 2019

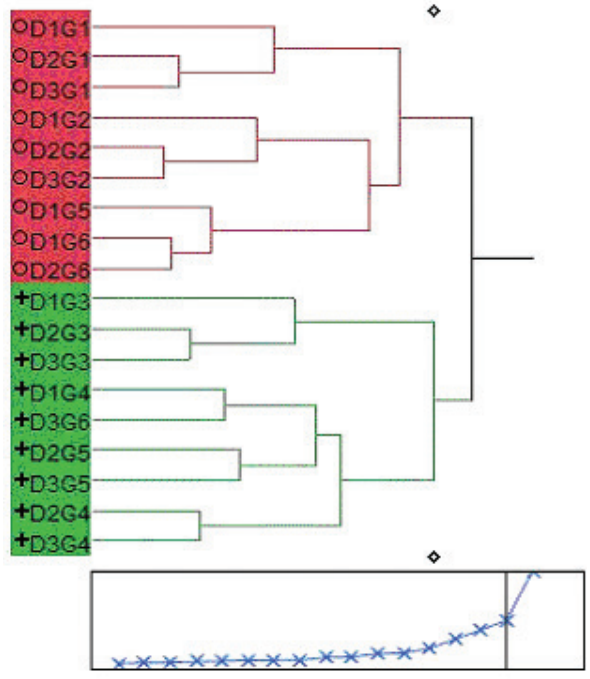

Fig. 7: Hierarchical Multivariate analysis of treatments by Ward's method in 2020

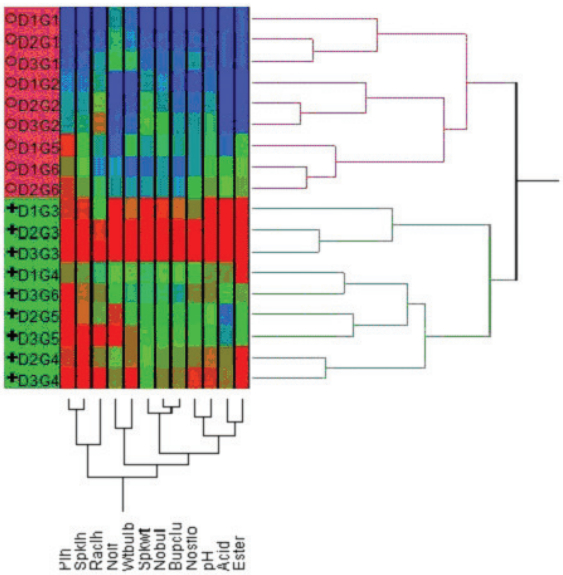

Fig. 8: Multivariate two clustering of treatments vis-à-vis traits in 2020

Second year of study

Two clusters of treatments had been observed as marked by clustering handle (Fig. 7). Treatments (D1G1, D2G1, D3G1 & D1G5, D2G6, D1G6, D2G2, D3G2) were clustered in first and separated by cluster of remaining treatments. Two dimensional clustering had also been carried out to group the traits as per variations observed in studied treatment combinations during field evaluation (Fig. 8). Traits plant height, spike length, rachis length were grouped and maintained distance from group consisted of Ester value, pH of oil, number of florets per spike.

Correlation analysis

First year of study

Highly significant direct correlation had been maintained by physical and chemical traits for considered treatment combinations as chemical traits would be enhanced with additional positive augmentation of physical traits (Table 5). High values of bulbs yield per clump with number of bulbs, weight of bulbs, spike weight, Acid value, number of florets per spike need to be mentioned (Madhumathi *et al.,* 2018). pH of oil had expressed highly significant values for number of bulbs, Number of florets per spike, spike length whereas Acid value exhibited for bulbs yield per clump, weight of bulb, number of florets per spike etc.

Second year of study

Significant positive values of correlation coefficients had been showed by physical and chemical traits for considered treatment combinations implied chemical traits would be enhanced with corresponding positive augmentation of physical traits (Table 6). High values of Bulbs yield per clump with spike weight, number of florets per spike, number of bulbs, weight of bulb number of bulbs, weight ob bulbs, spike weight, Acid value, number of florets per spike needs to be mentioned. pH of oil had expressed highly significant values for number of bulbs, number of florets per spike, spike length whereas Acid value exhibited for bulbs yield per clump weight of bulb, number of florets per spike etc.

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