ISSN: 2347-4688, Vol. 06, No.(1) 2018, pg. 54-64

Current Agriculture Research Journal

www.agriculturejournal.org/

Principal Component Analysis With Quantitative Traits in Extant Cotton Varieties (*Gossypium Hirsutum* L.) and Parental Lines for Diversity

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Abstract

The experimental material consisted of 101 extant varieties and parental lines characterized for morphological traits under Distinctiveness Uniformity and Stability (DUS) testing at CICR, Regional Station, Coimbatore, India. Twenty one quantitative traits were taken for observation. The data were utilised to estimate substantial variation and relationship within the extant varieties and to identify the best performing genotypes. Analysis of variance for quantitative traits, in diverse line, showed sizable amount of variability. The highest variation was found for vigour index, plant height, germination per cent, fibre maturity, yield per plant, plant stand, fibre uniformity and ginning per cent when mean performance genotypes were considered. Seed cotton yield showed significantly positive correlation with boll number plant^{-1} (0.95), boll weight^{-1} (0.53), lint weight (0.50), fibre length (0.27), plant growth habit (0.26), plant height (0.23) and seed index (0.21). Principal component analysis showed the extend of variation by components 1 to 8 that exhibited Eigen value >1. Cluster analysis based on various morphological traits assorted 101 extant varieties of cotton into three main clusters. Dendrogram arrived based on hierarchal clustering, grouped genotypes based on their morphological traits rather than the geography of origin.

Article History

Received: 07 May 2017
Accepted: 28 January 2018

Keywords:

Extant varieties,
DUS test,
Genetic diversity,
clustering,
Dendrogram,
Quantitative traits.

Introduction

In India, enactment of The PPVFR Act, 2001[1] not only facilitated the protection of plant varieties, Breeder's Right's but also ensured the availability of high quality seeds and planting materials to Indian farmers. It not only encourages the plant breeders but also stimulates investment on research and development, both in the public and private sector for the development of new varieties of plants.

A successful breeding program needs, complete knowledge and understanding of genetic diversity available within the resources. This enables to choose parents for generation of diverse population

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To Link to this Article: http://dx.doi.org/10.12944/CARJ.6.1.07

and selection. The main criteria considered for assessing genetic diversity and to identify genetic distances within the up land cotton varieties are morphological traits. This will set a path for the development of superior parents and heterotically potential hybrid combinations.

It was reported that cultivated cotton genotypes have narrow genetic base[2,3]. To broaden the genetic base through the hybrid breeding program, studies on the genetic divergence within genetic stock is a prerequisite. Genetic variations within and between different cotton genotypes for morphological and fibre quality traits have been studied for their improvement[4]. Principal component analysis (PCA) and linkage cluster analysis was employed by the researchers to find the similarity among the genotypes for the traits and their placement into different clusters[5,6].

Characterisation and documentation of qualitative and quantitative traits of extant cotton varieties and parental lines are mandatory requirement of Distinctiveness, Uniformity and Stability (DUS) testing programme towards the implementation of PPV & FR Act, 20011. As per this act, a new plant variety is considered for protection (IP protection), if that variety is clearly distinguishable by minimum one essential characteristic from other varieties whose existence is a matter of common knowledge in any country at the time of filling the application, and the variation in characteristic features must be uniform subject to further propagation and the same essential characteristics remain unchanged after subsequent propagation. The extant varieties were used as reference varieties (check varieties) in the DUS testing of new plant varieties. Grouping of extant varieties based on their qualitative and quantitative trait is essential and this will support the selection process of reference varieties for DUS testing of a new plant variety. Keeping this in mind, the DUS data along with ancillary data, generated under this programme, were subjected to Principal Component Analysis and cluster analysis for exploitation of diversity available among the varieties and parental lines. The information generated in this study would be useful for DUS testing of new plant varieties and also for inter varietal breeding.

Materials and Methods

The extant varieties of cotton were characterised for morphological traits under DUS testing as reference varieties at Central Institute for Cotton Research, Regional station, Coimbatore during 2012-14. The experimental material comprised of 101 extant cotton varieties (Table 4) for use as reference varieties, under DUS programme, received from varied agro ecological cotton growing zones of India. Sowing of seeds of each variety was taken up in Randomised Complete Block Design with three replications. Each variety was sown in 10 rows adopting 90 cm space between rows and 60 cm within rows. Recommended agronomic, cultural and plant protection practices for tetraploid cotton was adopted till the harvest of the crop.

The genotypes were evaluated for plant height (cm) by measurement of ten individual plants on 140th day of sowing, growth habit (cm) recorded by measuring the length of longest sympodia in randomly selected ten individual plants and the average was taken for analysis. The sympodia number and number of bolls plant^{-1} were counted in randomly selected 10 plants in each variety and the average was taken. Plant stand was assessed on 140th day in each plot; ten individual bolls harvested in each plot were weighed (g) and the mean values taken for statistical analysis. The harvested bolls were ginned in the laboratory after which lint weight and seed weight/boll (g), seed index and ginning percent were recorded, seed cotton yield/plant arrived through multiplication of a number of bolls/plant and boll weight. The harvested seeds were subjected to standard germination test by sowing 100 seeds in four replications in sand medium and the mean per cent was arrived[7]. For calculating the speed of germination, one hundred seeds were germinated in sterilized sand medium replicated four times. Number of seeds that germinated was counted daily up to the final counting day. From the mean per cent germination of each counting day, the speed of germination was derived. and expressed as numeral[8]. From standard germination test, randomly ten normal seedlings were taken for measuring the root and shoot length of individual seedlings. The length measured from the collar region to tip of primary root designated as Root length, similarly, shoot length from the collar region to the tip of the plumule. The mean value in each was expressed in cm. Vigour index (VI)[9] was computed by multiplying seedling length with germination per cent, Dry matter of seedlings (DMS) was estimated using hot-air oven dried (85 °C for 24 h and cooled in a desiccator) 10 normal seedlings. The fibre parameter includes fibre length (FL), fibre strength (FS), fibre fineness (FF), fibre uniformity (FU) and fibre maturity (FM) were measured in PRIMIER ART2 fully automated cotton testing instrument (ICC mode). Standard characteristic states were used to measure different morphological traits of cotton at appropriate growth stages.

Mean value of each trait in every genotype was computed for determining the analysis of variance. Pearson's linear correlation coefficient was used for 21 quantitative traits[10,11,12] (Table 1) and correlation matrix was arrived to compare various traits. Principal Component Analyses based on 21 quantitative traits were executed to find out the relative importance of different traits in capturing the genetic variation. The standardized values were used to perform PCA in PAST3 software[13]. Score plot was used for assessment of components or factors that could explain for major variability in the data. The factors correspond to 21 PCs were subjected to cluster analysis based on Euclidean distances and wards minimum variance using Agglomerative hierarchical clustering in XLSTAT software version 2016.05. A hierarchical cluster analysis was performed with pooled data using scores of dissimilarity matrix[14].

Results and Discussion

Under field and laboratory twenty one quantitative traits were observed for 101 extant varieties of cotton. Analysis of variance exposed considerable level of variability among accessions for majority of the traits observed. Basic descriptive statistics are presented for 21 characters in Table 1.

Table 1: Coefficient of variation for yield and other quantitative traits in extant varieties of upland cotton

Quantitative traits	Minimum	Maximum	Range	Mean deviation	Standard variation (%)	Coefficient of	Variance
Germination (%)	48.000	100.000	52.000	93.000	5.977	6.426	35.719
Speed of germination	5.930	24.300	18.380	18.320	3.081	16.817	9.495
Root length (cm)	8.010	15.890	7.880	9.850	1.209	12.269	1.461
Shoot length (cm)	5.200	12.430	7.230	8.900	1.538	17.278	2.366
Vigour index	636.360	2285.000	1648.640	1741.620	232.122	13.328	53880.679
Dry matter of seedling(g)	0.270	0.660	0.390	0.440	0.099	22.274	0.010
Plant: Height (cm)	52.670	166.000	113.330	95.340	21.734	22.796	472.370
Plant: Growth habit (cm)	17.560	55.330	37.780	32.710	7.402	22.629	54.796
Plant stand (%)	8.000	66.000	58.000	52.560	12.960	24.656	167.968
Number of sympodia $plant^{-1}$	11.700	33.300	21.600	18.680	3.937	21.079	15.497
Boll number/plant	6.000	29.000	23.000	15.660	5.425	34.633	29.428
Boll: Weight (g)	2.250	5.830	3.580	4.420	0.633	14.321	0.401
Lint weight (g)/10 bolls	7.600	22.100	14.500	15.900	2.494	15.690	6.220
Seed: Index	6.200	12.800	6.600	9.710	0.885	9.113	0.783
Ginning %	30.970	40.650	9.680	35.990	2.022	5.619	4.089
Fibre: Length	21.600	37.800	16.200	27.230	1.754	6.442	3.078
Fibre: Strength	18.200	31.800	13.600	21.450	1.837	8.560	3.373
Fibre: Fineness	3.250	7.000	3.750	4.450	0.492	11.062	0.243
Fibre: Uniformity	46.600	53.100	6.500	50.590	1.447	2.861	2.095
Fibre: Maturity	66.000	90.000	24.000	76.240	4.539	5.954	20.603
Seed cotton yield/plant (g)	15.750	135.780	120.030	70.080	27.625	39.419	763.137

The highest variation was found for vigour index, plant height, germination per cent, fibre maturity, yield per plant, plant stand, fibre uniformity and ginning percent. Relatively, low variation was noticed for dry matter of seedlings, boll weight, fibre fineness and seed index. The observed variability found among extant cotton genotypes can probably attribute to the inherent genetic differences and the environment in which they were grown. The correlation coefficients of characters attributed to seed cotton yield per plant were estimated and the results are presented in Table 2. Significant and positive correlation of seed cotton yield with boll number per plant (0.95), boll weight (0.53), lint weight (0.50), fibre length (0.27), plant growth habit (0.26), plant height (0.23) and seed index (0.21) was observed. This result indicated that the increase in seed cotton yield might be due to increase in one or more of the above traits. Association of seed cotton yield with boll weight were reported in earlier studies[15], for number of bolls and boll weight[16,17,18], for number of bolls[19].

The close relationship between yield and yield attributing traits will be exploited in selection programme which might be helpful in developing high yielding genotypes. Among the fibre quality traits, fibre length alone showed a positive association with seed cotton yield, a similar trend was reported[20,21]. Fibre strength and uniformity ratio was also found to exhibit a negative association with seed cotton yield which was in accordance with Erande *et. al.,*[21].

Regarding inter correlation, germination per cent had significant positive correlation with vigour index, speed of germination, shoot length and lint weight. The speed of germination exhibited positive correlation with shoot length, vigour index, dry matter of seedling, lint weight and fibre length. Plant stand has significant inter correlation with boll weight and lint weight. Root length showed positive significant correlation with vigour index. Shoot length showed positive significant inter correlation with vigour index. Shoot length and vigour index showed significant positive association with dry matter of seedling, fibre length and plant growth habit. Dry matter of seedlings had significant inter correlation with fibre length, lint weight, seed index and boll weight. Plant height has positive significant inter correlation with plant growth habit, number of sympodia plant^{-1}, fibre maturity and boll numbers/plant. Plant growth has positive inter correlation with number of sympodia plant^{-1}, boll number /plant and fibre maturity. Boll number per plant has positive significant inter correlation with boll weight and lint weight. Boll weight has positive inter correlation with lint weight, seed index and fibre length. Number of sympodia with fibre maturity, Lint weight with seed index, ginning percent and fibre length; seed index with fibre length and fibre strength; fibre strength with fibre uniformity; fibre fineness with fibre uniformity and fibre maturity and fibre uniformity with fibre maturity. These results clearly indicated that selection for any one of these traits leads to concurrent improvement of other traits as well as seed cotton yield. A significant positive association of fibre length was observed with boll weight, lint weight and seed index indicated that these important yield contributing traits were good indicators of fibre length improvement. The other fibre quality traits showed negative association with yield and yield attributing traits. It was found that linkage was the primary cause for negative correlation between yield and fibre quality traits and inter mating may be recommended to break this association[22].

Principal Components

The Principal Component Analysis is a multivariate statistical technique, to extract the important information from the data table and simplify the description of the data set. To discern patterns of variation, PCA was performed on all variables simultaneously. The Eigen values, variability (%) and cumulative (%) are presented in Table 3

Out of 21 principal components, eight components had extracted Eigen value of >1. This contributed for 83.11% of the variation among the extant cotton varieties. Principal component 1, contributed for 21.99%, to the total variability. The variation on principal component 1 was mainly attributed due to lint weight, shoot length, fibre length, boll weight and dry matter of seedlings. These results are in accordance with[23]. The PC2 contributed for 15.62% to the total variability and was depicted mainly by plant height followed by growth habit, fibre maturity, number of sympodia plant^{-1} and fibre fineness. The PC3 contributed for 12.71% of the total variability and was mainly attributed to vigour index, shoot length and speed of germination. Principal component 4 contributed 9.97% to the total variability and was mainly ascribed to ginning percent and fibre fineness

Table 2: Correlation coefficient for yield and quantitative traits in extant varieties of upland cotton

Traits	G	SG	PS	RL	SL	VI	DMS	PH	PGH	NSP	BNP	BW	LW	SI	GI	FL	FS	FF	FU	FM	SCYP
G	1.00	0.60	0.17	0.11	0.29	0.63	0.16	0.07	0.10	-0.03	0.05	0.17	0.20	0.00	0.06	0.15	0.03	0.05	-0.13	0.04	0.09
SG		1.00	0.13	-0.07	0.69	0.63	0.59	-0.03	0.12	-0.17	0.09	0.16	0.24	-0.05	0.19	0.23	0.00	-0.03	-0.18	0.03	0.12
PS			1.00	-0.01	0.08	0.10	0.18	-0.06	-0.06	0.02	-0.01	0.40	0.29	0.09	0.15	-0.11	-0.16	-0.01	0.10	-0.08	0.08
RL				1.00	0.11	0.58	-0.09	0.00	0.01	-0.07	-0.04	-0.09	-0.07	-0.07	-0.02	0.03	0.10	-0.13	0.05	-0.02	-0.07
SL					1.00	0.78	0.75	0.13	0.28	-0.10	0.16	0.15	0.18	0.07	0.09	0.30	0.01	-0.15	-0.28	-0.06	0.17
VI						1.00	0.48	0.11	0.21	-0.11	0.09	0.12	0.16	0.01	0.07	0.25	0.07	-0.13	-0.19	-0.02	0.10
DMS							1.00	-0.01	0.12	-0.05	0.09	0.20	0.25	0.22	0.13	0.37	0.13	-0.18	-0.31	-0.13	0.12
PH								1.00	0.96	0.63	0.21	0.04	-0.02	-0.13	0.02	-0.04	-0.16	0.14	-0.10	0.26	0.23
PGH									1.00	0.57	0.26	0.04	0.00	-0.19	0.10	-0.03	-0.15	0.15	-0.09	0.31	0.26
NSP										1.00	0.20	-0.04	-0.11	-0.13	-0.05	-0.07	-0.08	0.09	-0.07	0.21	0.16
BNP											1.00	0.25	0.24	0.06	0.10	0.19	-0.17	0.05	-0.26	0.19	0.95
BW												1.00	0.90	0.53	0.18	0.31	-0.22	-0.16	-0.27	-0.13	0.53
LW													1.00	0.50	0.46	0.43	-0.17	-0.12	-0.34	-0.04	0.50
SI														1.00	-0.22	0.52	0.23	-0.31	-0.30	-0.29	0.21
GI															1.00	-0.01	-0.33	0.23	-0.06	0.27	0.15
FL																1.00	0.19	-0.43	-0.76	-0.31	0.27
FS																	1.00	-0.22	0.27	-0.22	-0.24
FF																		1.00	0.31	0.76	0.00
FU																			1.00	0.21	-0.32
FM																				1.00	0.13
SCYP																					1.00

Values in bold are significant at 0.05

G Germination(%); SG Speed of germination; PS Plant stand (%); RL Root length (cm); SL Shoot length (cm); VI Vigour Index; DMS Drymatter of Seedlings; PH Plant height (cm); PGH Plant Growth habit; NSP Number of sympodia /plant; BNP Boll number/plant; BW Boll weight (g); LW Lint weight(g); SI Seed index (%); GI Ginning (%); FL Fibre length; FS Fibre strength; FF Fibre fineness; FU Fibre uniformity; FM Fibre maturity; SCYP -Yield (g) with their positive loadings and negative loadings with plant height and number of sympodia plant^{-1}. The PC5 described contribution of 6.40% to the total variability, illustrated primarily the divergence in plant stand and boll weight with their positive loadings and negative loadings with boll number/plant. The first three PCs exhibited high variation for the traits under study and therefore good cotton improvement may be accomplished through inter varietal development.

Table 3: Principal component analysis for first eight components in extant varieties of upland cotton

Characters	Principal Components							
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Germination (%)	0.213	0.041	0.263	0.134	0.106	0.162	0.106	0.206
Speed of germination	0.290	0.014	0.329	0.173	-0.096	-0.201	0.122	-0.054
Plant stand (%)	0.110	-0.002	-0.047	0.296	0.540	-0.015	0.056	-0.347
Root length (cm)	0.026	-0.038	0.224	-0.066	0.105	0.688	-0.279	0.078
Shoot length (cm)	0.322	0.020	0.329	-0.030	-0.078	-0.146	0.042	-0.167
Vigour index	0.292	0.010	0.414	0.006	0.040	0.299	-0.059	0.025
Dry matter of seedling (g)	0.303	-0.063	0.203	-0.007	-0.030	-0.374	0.136	-0.135
Plant: Height (cm)	0.065	0.412	0.019	-0.336	0.263	-0.069	-0.063	0.113
Plant: Growth habit (cm)	0.104	0.426	0.083	-0.290	0.200	-0.098	-0.042	0.066
No. of sympodia plant-1	-0.014	0.326	-0.070	-0.323	0.258	-0.095	0.009	0.002
Boll number/plant	0.200	0.240	-0.215	-0.071	-0.349	0.279	0.272	-0.344
Boll Weight (g)	0.304	-0.014	-0.312	0.181	0.304	0.064	0.054	0.077
Lint weight(g)/10 bolls	0.327	-0.017	-0.280	0.244	0.153	0.026	-0.054	0.253
Seed Index	0.201	-0.245	-0.261	-0.108	0.150	0.009	0.259	0.325
Ginning %	0.104	0.171	-0.040	0.382	-0.080	-0.109	-0.379	0.121
Fibre Length(mm)	0.305	-0.188	-0.104	-0.243	-0.205	-0.048	-0.126	0.291
Fibre Strength (g/tex)	-0.041	-0.237	0.155	-0.224	0.062	0.061	0.523	0.265
Fibre Fineness (micronaire)	-0.140	0.321	0.046	0.311	-0.151	-0.041	0.205	0.317
Fibre Uniformity (%)	-0.282	0.045	0.138	0.218	0.266	0.128	0.400	-0.096
Fibre Maturity (%)	-0.073	0.382	0.049	0.221	-0.199	0.034	0.164	0.355
Yield/plant (g)	0.268	0.214	-0.294	-0.016	-0.220	0.257	0.232	-0.255
Eigen value	4.617	3.280	2.670	2.094	1.343	1.299	1.147	1.004
Variability (%)	21.986	15.617	12.714	9.972	6.396	6.187	5.460	4.780
Cumulative (%)	21.986	37.603	50.317	60.289	66.685	72.872	78.332	83.112

Score Plot

The principal component scatter plot of the cotton accessions depicted that the accessions those were close together were perceived as being similar when rated based on the variables. Thus accessions RST-9 and F 505, CPD 428 and ACP 71, LRA 5166 (SB) and VIKRAM, PG 5 and RHC 005 were close to each other on both PC1 and PC2 respectively. The accessions SRT GMS-1, Surat Dwarf, LRA 5166, GSAV 1056, GSB 39 and DHY 286-1 were separated from other accessions. The accession SRT GMS-1 was opposite to GMS 39 because SRT GMS-1 lied in the negative region and GMS 39 lied in positive region. The genotypes in the positive ordination may be utilized for heterosis breeding program (Fig.1, Table 4).

Biplot

These variables were super imposed on the plot as vectors in the biplot, the relative length of the vector represents the relative proportion of variability in each variable. The extant variety distant from origin showed more variation and less similarity with other varieties. Traits such as fibre fineness, fibre maturity, number of sympodia plant^{-1}, plant growth habit, plant height, boll number per plant, yield per plant, germination percent, speed of germination, shoot length, vigour index, lint weight per plant, boll weight per plant, dry matter of seedlings, fibre length and seed index were well represented with high amount of variability, while root length and plant stand showed the lowest variability. The quality traits, such as fibre uniformity, strength were not in desirable direction (Fig. 2). A similar result of least variability in fibre uniformity in cotton was reported[23]. The range of variability in each trait, among the varieties under study, exhibited greater divergence which may be useful for an effective cotton breeding program.

Table 4: Grouping of genotypes based on the score plot of Principal component analysis

S.No.	Groups	Name of extant varieties
1	A	70 E, AB 6, ACP 71, Ca/H-128, Ca/ H-129, Ca/ MH -133, CPD 423, CSH -8, CSH-19, DHY 286-1, H 1098, M 12, NH 452, VC 21, J 34, LH 1134, LSS, L 389, HS 6, AC738, AH 107, AK 23 B, AK 32, AKH 07 R, Bikaneri Nerma, MDH 89, CPD 420, CPD 428, DS 28 F, G COT 18, Gujarat 67, H 1117, H 1157, K 34007, BN Red, MCU 13, MCU 4, PRS 74, PUSA 8-6, Reba B50, RHC 003, RST -9, SH-2379, Suman, T 7, TCH 1218, H 1220, VC 22 , Vikas , Vikram, H 974, HHM -1, F 286, F 320, LH 372, J 205, Badnawar 1, Khandwa 3, AKH 081, F 1054, F 1378, F 1861, G COT 16, PIL 43, HLS 329, Kanchana, M 2 , MCU 3, MCU 7, MCU 8, NCH 11, PH 325, PH 93, RS- 810, RS-875, VC 31, VC 32, LH 886, GSHV 112, Deviraj, F 505, F 846, G COT 10, G COT 100, LH 1556, LH 900, PIL 8 , RHC 006, KH 11, PG 5, PG 6, JK 35, L 604, LRA 5166 (SB), Khandwa 2
2	B	GSB 39
3	C	SURAT DWARF, LRA 5166, RS-2013
4	D	SRT-GMS 1, GSAV 1056

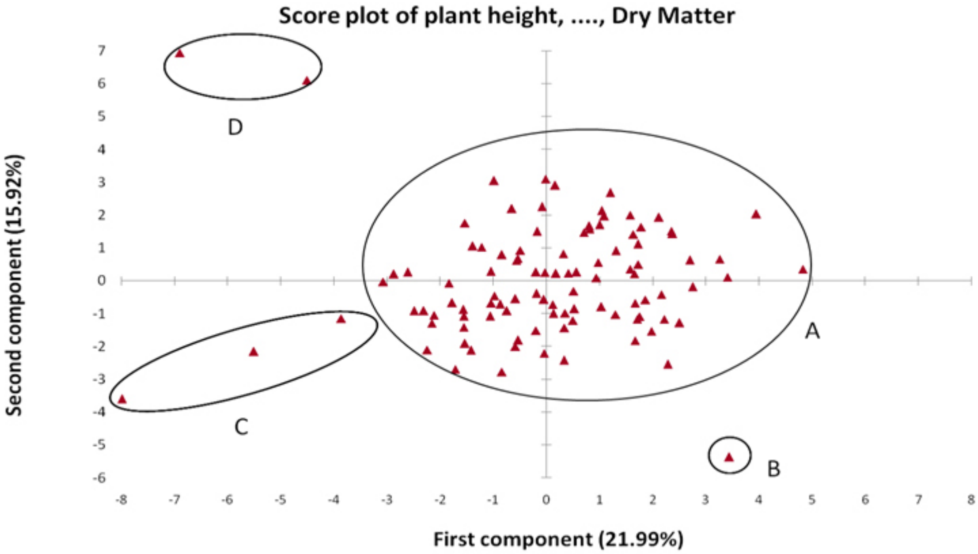

Fig. 1: Two dimensional ordinates of 101 extant varieties of upland cotton

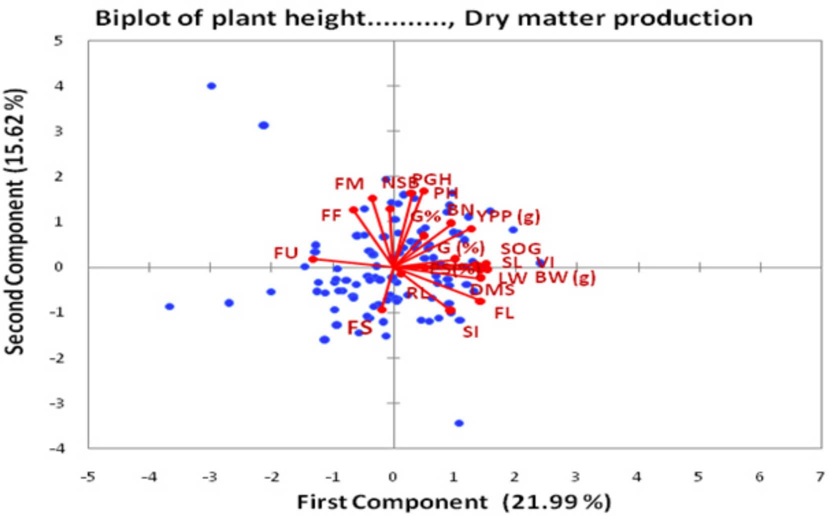

Fig. 2: Principal component's Biplot of 101 upland cotton extant varieties

Clustering

The factors corresponding to 21 PCs were subjected to cluster analysis based on Agglomerative hierarchical clustering performed on the Euclidean distance matrix utilizing Ward's linkage method and the resultant dendrogram showed three distinct clusters (Fig.3). The cluster II was the biggest comprising of 47 genotypes followed by cluster III, which occupies 35 genotypes and cluster I with 19 genotypes (Table 5). The cluster analysis identifies groups of cotton cultivars those were of more closely related as reported[24]. These results are in confirmation with the earlier studies of[25,26]. The geographical distribution of genotypes is not the lone factor that causes morphological and genetic diversity. It may be the outcome of several other factors like natural or artificial selection, exchange of breeding materials, genetic drift and environmental variations. Therefore, the emphasis for selection of parents should be based on genetic rather than geographical diversity.

Table 5: Grouping of genotypes based on clustering upon yield and quantitative traits in extant Gossypium hirsutum varieties

Clusters	Number	Name of extant varieties
I	19	70 E, AB 6, ACP 71, Ca/H-128, Ca/ H-129, Ca/ MH -133, CPD 423, CSH -8, CSH-19, DHY 286-1, H 1098, M 12, NH 452, VC 21, J 34, LH 1134, LSS, L 389, HS 6
II	47	AC738, AH 107, AK 23 B, AK 32, AKH 07 R, Bikaneri Nerma, MDH 89, CPD 420, CPD 428, DS 28 F, G COT 18, Gujarat 67, H 1117, H 1157, K 34007, BN Red, MCU 13, MCU 4, PRS 74, PUSA 8-6, Reba B50, RHC 003, RST -9, SH-2379, Suman, T 7, TCH 1218, H 1220, VC 22 , Vikas , Vikram, H 974 , HHM -1, F 286, F 320, LH 372, J 205, Badnawar 1 , Khandwa 3, GSB 39, G SAV 1056, AKH 081, F 1054, F 1378, F 1861, G COT 16, PIL 43
III	35	HLS 329, Kanchana, LRA 5166, M 2 , MCU 3, MCU 7, MCU 8, NCH 11, PH 325, PH 93, RS -2013, RS- 810, RS-875, VC 31, VC 32, LH 886, GSHV 112, SRT-GMS 1, Deviraj, F 505, F 846, G COT 10, G COT 100, LH 1556, LH 900, PIL 8 , RHC 006, Surat Dwarf, KH 11, PG 5, PG 6, JK 35, L 604, LRA 5166 (SB) , Khandwa 2

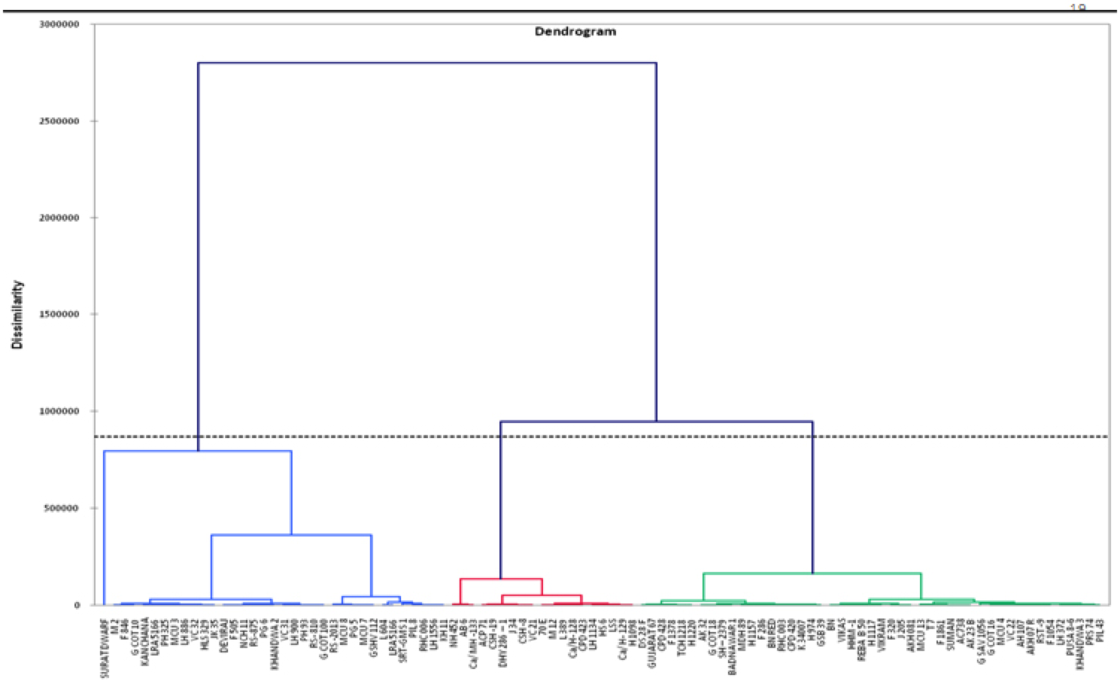

Fig. 3: Dendrogram based on Ward's linkage method of 101 extant varieties of upland cotton

Cluster analysis using Ward's method of minimum variance exhibited a distinct pattern of group formation (Table 6). The genotypes in cluster I showed higher values for germination per cent, rate of germination, root and shoot length, vigour index, dry matter of seedlings, plant growth habit, boll weight, ginning (%), fibre length, fibre maturity and lint weight/10 bolls. Similarly, cluster II was comprised of genotypes having the highest values for plant height, seed index, fibre strength, boll number/plant and yield/plant. The members of the III cluster were characterized by higher values for plant stand (%), fibre fineness, fibre uniformity and number of sympodia plant^{-1}.

Table 6: Mean values of clusters for various traits in extant varieties of upland cotton

Characters	Cluster I	Cluster II	Cluster III
Germination (%)	94.684	93.915	89.943
Speed of germination	20.049	19.104	16.340
Root length (cm)	11.124	9.810	9.215
Shoot length (cm)	10.573	9.230	7.558
Vigour index	2050.888	1786.695	1513.205
Dry matter of seedling (g)	0.502	0.453	0.396
Plant: Height (cm)	97.436	99.360	88.809
Plant: Growth habit (cm)	35.006	34.099	29.603
Plant stand (%)	53.895	50.638	54.429
No. of sympodia plant^{-1}	18.500	18.598	18.874
Boll number/plant	15.526	16.333	14.838
Boll Weight (g)	4.468	4.414	4.400
Lint weight (g)/10 bolls	16.121	15.966	15.677
Seed Index	9.574	9.783	9.689

Ginning %	36.347	35.840	35.994
Fibre Length (mm)	27.603	27.349	26.873
Fibre Strength (g/tex)	21.495	21.680	21.130
Fibre Fineness (micronaire)	4.318	4.439	4.541
Fibre Uniformity (%)	50.445	50.512	50.781
Fibre Maturity (%)	76.500	76.309	76.000
Yield /plant (g)	68.750	73.565	66.120

ation was found for vigour index, plant height, germination percent, fibre maturity, yield per plant, plant stand, fibre uniformity and ginning percent. Seed cotton yield exhibited significantly positive correlation with boll number per plant, boll weight, lint weight, fibre length, plant growth habit and plant height. The Principal component analysis summarized maximum diversity present among the genotypes in eight components. In the cluster analysis the genotypes like Surat Dwarf, GSAV 1039, DHY 39, SRT GMS-1, forms different clusters and in the biplot also it found distantly when compared to rest of the genotypes. So, these varieties may be useful for further breeding programme to develop high yielding cultivars. The classification of varieties into different clusters, aids for selection of genotypes for designed future breeding program. Varieties which are in diverse nature may be useful for transfer of the desired gene for cotton yield improvement, suitable for different ambiances.

Acknowledgements

The author acknowledges, the technical support rendered by Ms.H.Kavitha, Research Associate while recording of observations under DUS project. I wish to thank Dr. C. Priyadarshini, Senior Research fellow for her support in preparation of this manuscript. I thank The PPV and FRA New Delhi for generous funding and technical support extended in execution of work during the project period.

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