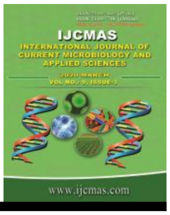
Int.J.Curr.Microbiol.App.Sci (2020) *9*(3): 2943-2956

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 3 (2020)**
Journal homepage: http://www.ijcmas.com



Original Research Article

https://doi.org/10.20546/ijcmas.2020.903.338

Principal Component Analysis of Physiological Traits Governing Drought Tolerance in Germplasm Accessions of Green Gram [*Vigna radiata* (L.)]

M. S. P. Kanavi[1*], N. Nagesha[2], G. Somu[3], B. T. Krishnaprasad[4] and S. Rangaiah[5]

[1]*Department of Genetics and Plant Breeding, College of Agriculture, Hassan,*
University of Agricultural Sciences, Bangalore, Karnataka, India
[2]*Department of Plant Biotechnology, College of Agriculture, G.K.V.K,*
University of Agricultural Sciences, Bangalore, Karnataka, India
[3]*Assistant Breeder, AICRP on Sorghum, Chamarajanagara,*
University of Agricultural Sciences, Bangalore, Karnataka, India
[4]*Department of Agricultural Biotechnology, College of Agriculture, Hassan,*
University of Agricultural Sciences, Bangalore, Karnataka, India
[5]*Department of Genetics and Plant Breeding, College of Agriculture, G.K.V.K,*
University of Agricultural Sciences, Bangalore, Karnataka, India

**Corresponding author*

ABSTRACT

Keywords

Green gram, Drought tolerance, Physiological traits,Principal component analysis, Biplot analysis

Article Info

Accepted:
25 February 2020
Available Online:
10 March 2020

An experiment was conducted to evaluate 200 green gram germplasm accessions along with five check entries for drought tolerance using augmented design during summer 2015 by imposing drought stress condition. Observations were recorded on 17 quantitative traits. ANOVA revealed high significant differences among germplasm accessions for yield and for drought tolerant physiological traits. Mean squares attributable to 'Genotypes *vs* check entries' were significant for all the traits except relative water content. Principal component analysis was carried out for 6physiological traits showing positive correlation with yield. Out of 6 factors generated by PCA, there are only 2 factors with eigenvalues more than or close to one contributing for more than 88.03 % of variability. Among the variables studied, variable proline content (11.91) had highest *per cent* contribution to the total variability followed by spad chlorophyll meter reading (10.80), leaf water potential (10.75), Relative water content (8.51) and specific leaf area (6.31).

Introduction

Green gram [*Vigna radiata* (L.) Wilczek] also known as mung bean is an important short duration pulse crop of the tropical and subtropical countries of the world. . It is a prehistoric crop and grown throughout Asia. Green gram is the third most important pulse crop of India after chickpea and red gram.It belongs to papilionoid subfamily of the

Fabaceae family and has a diploid chromosome number of $2n=2x=22$. Green gram as a legume crop has the ability to fix atmospheric nitrogen via root rhizobial symbiosis leading to improved soil fertility and texture (Graham and Vance, 2003).The protein content of pulses are twice that of cereals (20-25%) and almost equal to that of meat and poultry hence commonly pulses are called as poor man's meat (Reddy, 2009).India is the major pulse producing country in the world which shares 30-35% and 27-28% of the total area and production respectively (Shao *et al.*, 2018). In India mung bean is cultivated in an area of 40.70 lakh hectare with production of 19.01 lakh tones and productivity of 467 kg ha^{-1}.

Average productivity of mung bean in India is one of the lowest compared to world average since it is mainly cultivated on marginal and poor fertile soils under rainfed condition in rabi or late rabi season utilizing available residual soil moisture after harvesting kharif crop. Hence crop is expected to undergo several kinds of droughts during its cropping period.

Crop is likely to experience severe droughts in days to come because of global warming and climate change which are adding to the woes of reduced soil moisture availability to crop growth and production. Drought is the major environmental stress severely impairing plant growth and development limiting performance and production of crop plants than any other environmental stresses (Shao *et al.*, 2009). Drought is the major constraint for green gram production in India due to erratic and insufficient rainfall (Baroowa and Gogoi., 2015).

Droughtis a multidimensional stress which disturbs normal metabolism and yield of crop plants. Climate change at global level is rapidly increasing the frequency of severe drought conditions (Dai, 2012).

The plants possess a wide range of physiological and genetic adaptations innate or triggered to combat the stress ranging from transient responses to low soil moisture to major survival mechanisms of escape by early flowering in absence of seasonal rainfall (Supratima, 2016).Some of the commonly observed drought tolerance mechanisms adapted by the plants are; longer root length, longer root to shoot ratio, leaf waxing, reduced transpiration, reduced photosynthesis, proline accumulation, ABA accumulation, prevention of chlorophyll degradation, ionic balance, balance of water status, stomatal behavior, photosynthetic efficiency, carbon allocation and utilization. Studying water stressthrough quantification of physiological responses of plants under water stress is a viable, reliable and accurate approach (Kursar *et al.*, 2009).Selection efficiency in breeding for water stresscould be enhanced if particular physiological or morphological attributes related to yield under stress environment could be identified and employed as selection criteria for complementing traditional plant breeding (Rowland *et al.*, 2018).While designing a breeding program to improve drought tolerance of a crop plant, it is necessary to gain knowledge concerning both the genetics and physiological mechanisms (Clarke and Townley, 1984). Therefore, physiological traits with strong correlation of plants response to drought are crucial in understanding and exploring water stress mechanisms (Maréchaux *et al.*, 2015).

Multivariate analysis such as principal component analysis usually starts out with data involving a substantial number of correlated variables. Principal Component Analysis (PCA) is a very powerful dimension-reduction technique that can be used to reduce a large set of variables to a small set of variables that still contains most of the information of the larger set. Principal component analysis(PCA) is a statistical /

mathematical procedure that transforms more number of correlated variables into a smaller number of uncorrelated variables called as principal components.

The first principal component with highest PCA coefficient /eigenvalue accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible with corresponding PCA coefficients /eigenvalues.

Materials and Methods

The experiment was conducted at experimental plot of College of Agriculture, Hassan, University of Agricultural Sciences, Bangalore. The experimental site is geographically located at Southern Transitional Zone (Zone-7) of Karnataka with an altitude of 827 m above Mean Sea Level (MSL) and at 33′ N latitude and 75^0 33′ to 76^0 E38′ longitude. The study material consisted of 200 germplasm accessions collected from different research institutions / organizations representing different agro-climatic zones. List of germplasm accessions used in the study with their source is given in table No1.

Layout of the experiment

The experiment was conducted in an Augmented Randomized Complete Block Design with 200germplasm accessions. As per the augmented RCBD, the check entries were replicated twice randomly in each block. There were 5 blocks, each block had 5 plots of size 3x3 m^2 thus each block size was 15 m^2. The gross area of experimental plot was 75 m^2. The row spacing was 30 cm and inter plant distance was 10 cm. The experiment was conducted during *summer* 2015. Recommended crop production practices were followed to raise healthy crop.

Imposing drought condition

Drought condition was imposed by withholding irrigation 25 days after sowing (Baroowa and Gogoi, 2015; Pooja *et al.*, 2019). Since the experiment was conducted during *summer* season, there were no unpredicted rains during the entire cropping period hence the drought condition was effectively imposed. The rainfall data of experimental site during the cropping period is given in table No.2.

Plant sampling and data collection

Observations were recorded on five randomly chosen competitive plants from each germplasm accession for all the physiological traits. The values of five competitive plants were averaged and expressed as mean of the respective characters. The observations were taken on the traits like; Threshing %, Harvest index (%),SCMR (SPAD Chlorophyll meter reading), Leaf water potential(Mpa), Proline content ($\mu g\, g^{-1}$), Relative water content, Specific leaf area and Seed yield per plant.

Statistical analysis

Analysis of variance (ANOVA)

The quantitative trait mean value of five randomly selected plants in each of the genotype and check entries were used for statistical analysis. ANOVA was performed to partition the total variation among genotypes and check entries into sources attributable to ‘Genotypes + Check entries’, Genotypes’, Check entries’ and Genotypes vs check entries’, following the augmented design as suggested by Federer (1956) using statistical package for augmented design SAS version 9.3 and IndoStat. The adjusted trait mean of each of the genotype was estimated (Federer, 1956) and the same was used for all subsequent statistical analysis.

Multivariate analysis

Factor analysis, using the Principal Component Analysis (PCA) as extraction method and Varimax rotation, was performed to verify if the assay data variation and obtained factors could explain genotype performance and identify drought tolerance controlling factors.

Biplot analysis was presented by first two principal component analysis (PCA) which were computed based on rank correlation matrix using data from 6 physiological traits by Microsoft Excel (2007) and XLSTAT 2014, Copyright Addinsoft 1995-2014 (http://www.xlstat.com) as described by Iqbal *et al.*, (2014).

Results and Discussion

Analysis of variance (ANOVA)

Analysis of variance revealed highly significant mean squares attributable to germplasm accessions for all the traits. Significant mean squares were recorded for all the traits. (Table 3). Mean squares attributable to 'Genotypes *vs* check entries' were significant for all the traits except relative water content. These results suggest significant differences among the germplasm accessions. The germplasm accessions as group differed significantly for all of the traits under investigation, similarly, check entries as group differed significantly for most of the traits under study.Hemavathy *et al.*, (2014) has also reported that green gram germplasm differed significantly for all the traits under study.

Multivariate analysis

The first principal component with highest PCA coefficient/ eigenvalue accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible with corresponding eigenvalue /PCA coefficient.

Principal component analysis has to be performed only for those traits (independent variables) having positive correlation with dependent variable yield. Hence correlation studies were first carried out to identify physiological traits to be considered for principal component analysis.

Correlation coefficient analysis

Correlation coefficients are used to measure the strength of the relationship between two variables (dependent and independent). Pearson *correlation* which is one of the most commonly used statistics was performed. Among the independent variables, proline content had highest positive correlation with seed yield per plant(0.63) followed by spad chlorophyll meter reading (0.62), leaf water potential (0.61), harvest index (0.60), relative water content (0.51) and specific leaf area (0.41). Correlation matrix is given in the table 4.

Sandhiya and Saravanan (2018) have reported significant positive correlation with traits, number of pods per plant, number of clusters per plantand number of pods per cluster in mungbean.Pooja *et al.*, (2019) has also reported positive correlation of leaf area with RWC (0.57), membrane stability index (0.39) and protein content (0.35) under drought condition in green gram.

Kaiser-Meyer-Olkin (KMO) test

KMO test measures whether the data is suitable for factor analysis like PCA. The test measures sampling adequacy for each variable in the model andfor complete model. Lower the proportion, more the data is suited for factor analysis. KMO values between 0.8 and 1 indicate the sampling is adequate. KMO values less than 0.6 indicate the sampling is not adequate and that remedial action should be taken. KMO test results are given in table 5.All the 6 physiological traits considered for study satisfied the conditions of KMO test

Principal component analysis

Principal component analysis of physiological traits governing drought tolerance was performed and eigenvalues are presented in table 6. The first two factors explain 88.03 *per cent* of the total variability controlled by physiological traits. Highest factor loadings / component coefficients were recorded by proline content (0.98) followed by Spad chlorophyll meter reading, leaf water potential (0.92), relative water content (0.87), harvest index (0.78) and specific leaf area (0.72). Factor loading values are presented in table 7.

The analysis will simply identify factors / principal component numbers. It is the researcher who has to decide which variable to be considered. In making decision to identify variables depending upon our research interest one should refer to factor loadings or component coefficient values which are correlation coefficients between variables and the factors. These values will help in making decision to identify variables having maximum contribution for total variability

Table.1 List of germplasm accessions used in the study and their source

Sl. No.	Germplasm	Location
1	KM13-16	ARS, Bidar
2	KM13-19	ARS, Bidar
3	KM13-39	ARS, Bidar
4	GG13-7	ARS, Bidar
5	GG13-6	ARS, Bidar
6	KM13-44	ARS, Bidar
7	GG13-10	ARS, Bidar
8	SML-668	ARS, Bidar
9	KM13-9	ARS, Bidar
10	IPM99-125	ARS, Bidar
11	LGG-596	RARS, Guntur
12	LGG-572	RARS, Guntur
13	LGG-450	RARS, Guntur
14	LGG-583	RARS, Guntur
15	LGG-590	RARS, Guntur
16	LGG-588	RARS, Guntur
17	LGG-589	RARS, Guntur
18	LGG-579	RARS, Guntur
19	LGG-562	RARS, Guntur
20	LGG-582	RARS, Guntur
21	LGG-585	RARS, Guntur
22	AKL-170	NBPGR, Akola
23	PLM-110	UAS, Bangalore

24	LGG-577	RARS, Guntur
25	IC-436624	IIPR, Kanpur
26	IC-436723	IIPR, Kanpur
27	IC-413316	IIPR, Kanpur
28	IC-436746	IIPR, Kanpur
29	VGG10-010	TNAU, Coimbatore
30	VGG04-011	TNAU, Coimbatore
31	VGG04-007	TNAU, Coimbatore
32	COGG-93	TNAU, Coimbatore
33	VBNGG-2	TNAU, Coimbatore
34	TARM-2013	TNAU, Coimbatore
35	VGG04-005	TNAU, Coimbatore
36	COGG-920	TNAU, Coimbatore
37	VGG07-003	TNAU, Coimbatore
38	VGG10-002	TNAU, Coimbatore
39	VGG-112	TNAU, Coimbatore
40	IC-92048	NBPGR, Akola
41	AKL-103	NBPGR, Akola
42	AKL-39	NBPGR, Akola
43	AKL-106	NBPGR, Akola
44	AKL-225	NBPGR, Akola
45	AKL-95	NBPGR, Akola
46	AKL-194	NBPGR, Akola
47	AKL-212	NBPGR, Akola
48	AKL-195	NBPGR, Akola
49	AKL-211	NBPGR, Akola
50	KM13-11	ARS, Bidar
51	KM13-30	ARS, Bidar
52	KM13-45	ARS, Bidar
53	KM13-18	ARS, Bidar
54	KM13-5	ARS, Bidar
55	KM13-02	ARS, Bidar
56	KM13-37	ARS, Bidar
57	KM13-23	ARS, Bidar
58	KM13-55	ARS, Bidar
59	KM13-12	ARS, Bidar
60	GG13-9	ARS, Bidar
61	KM13-49	ARS, Bidar
62	GG13-4	ARS, Bidar
63	GG13-54	ARS, Bidar
64	KM13-20	ARS, Bidar
65	GG13-5	ARS, Bidar

66	Chinamung	ARS, Bidar
67	GG13-2	ARS, Bidar
68	KM13-26	ARS, Bidar
69	KM13-47	ARS, Bidar
70	KM13-41	ARS, Bidar
71	KM13-11	ARS, Bidar
72	KM13-42	ARS, Bidar
73	GG13-11	ARS, Bidar
74	GG13-8	ARS, Bidar
75	GG13-12	ARS, Bidar
76	KM13-48	ARS, Bidar
77	IPM2-3	ARS, Bidar
78	IPM2-14	ARS, Bidar
79	PDM-139	ARS, Bidar
80	LGG-580	RARS, Guntur
81	PM-112	TNAU, Coimbatore
82	LGG-578	NBPGR, Akola
83	LGG-563	NBPGR, Akola
84	LGG-594	NBPGR, Akola
85	TM-96-2	NBPGR, Akola
86	LGG-593	NBPGR, Akola
87	LGG-591	NBPGR, Akola
88	PM-115	NBPGR, Akola
89	LGG-587	NBPGR, Akola
90	PM-113	NBPGR, Akola
91	LGG-586	NBPGR, Akola
92	IC-436775	NBPGR, Akola
93	IC-413311	NBPGR, Akola
94	IC-398984	NBPGR, Akola
95	IC-436767	NBPGR, Akola
96	IC-436573	NBPGR, Akola
97	LGG-584	NBPGR, Akola
98	LGG-592	NBPGR, Akola
99	LGG-555	NBPGR, Akola
100	LGG-564	NBPGR, Akola
101	LGG-460	RARS, Guntur
102	LGG-595	RARS, Guntur
103	LGG-566	RARS, Guntur
104	IC-553514	IIPR, Kanpur
105	IC-413319	IIPR, Kanpur
106	IC-436542	IIPR, Kanpur
107	IC-546493	IIPR, Kanpur
108	IC-436594	IIPR, Kanpur

109	IC-436630	IIPR, Kanpur
110	IC-436668	IIPR, Kanpur
111	IC-436555	IIPR, Kanpur
112	IC-413314	IIPR, Kanpur
113	AKL-20	NBPGR, Akola
114	AKL-89	NBPGR, Akola
115	AKL-228	NBPGR, Akola
116	AKL-184	NBPGR, Akola
117	AKL-182	NBPGR, Akola
118	AKL-230	NBPGR, Akola
119	AKL-229	NBPGR, Akola
120	AKL-86	NBPGR, Akola
121	IC-436646	IIPR, Kanpur
122	IC-343964	IIPR, Kanpur
123	IC-436528	IIPR, Kanpur
124	IC-436723	IIPR, Kanpur
125	IC-546491	IIPR, Kanpur
126	IC-546481	IIPR, Kanpur
127	IC-398988	IIPR, Kanpur
128	VGG10-005	TNAU, Coimbatore
129	VBN-223	TNAU, Coimbatore
130	COGG-912	TNAU, Coimbatore
131	VBN(G9)-3	TNAU, Coimbatore
132	ML-1165	TNAU, Coimbatore
133	VGG04-025	TNAU, Coimbatore
134	VGG04-004	TNAU, Coimbatore
135	VGG04-149	TNAU, Coimbatore
136	COGG-954	TNAU, Coimbatore
137	VGG08-002	TNAU, Coimbatore
138	VBN-1	TNAU, Coimbatore
139	VGG-119	TNAU, Coimbatore
140	VC3890-A	TNAU, Coimbatore
141	DGGV-4	UAS, Raichur
142	KPS-1	UAS, Raichur
143	CGG-973	UAS, Raichur
144	CN9-5	UAS, Raichur
145	KPS-2	UAS, Raichur
146	VC-6173	UAS, Raichur
147	VC-6368	UAS, Raichur
148	CO-6	UAS, Raichur
149	Harsha	UAS, Raichur
150	PLM-92	UAS, Bangalore
151	MH-709	UAS, Raichur

152	LGG-460	RARS, Guntur
153	KGS-5	UAS, Raichur
154	Barimung-4	UAS, Raichur
155	AKL-189	NBPGR, Akola
156	AKL-168	NBPGR, Akola
157	AKL-218	NBPGR, Akola
158	AKL-179	NBPGR, Akola
159	AKL-185	NBPGR, Akola
160	AKL-163	NBPGR, Akola
161	COGG-912	TNAU, Coimbatore
162	IC-73451	NBPGR, Akola
163	IC-105690	NBPGR, Akola
164	IC-73534	NBPGR, Akola
165	IC-73412	NBPGR, Akola
166	IC-39605	NBPGR, Akola
167	IC-73472	NBPGR, Akola
168	IC-92053	NBPGR, Akola
169	IC-73779	NBPGR, Akola
170	IC-73462	NBPGR, Akola
171	IC-118992	NBPGR, Akola
172	IC-53783	NBPGR, Akola
173	IC-73456	NBPGR, Akola
174	IC-73458	NBPGR, Akola
175	AKL-105	NBPGR, Akola
176	AKL-213	NBPGR, Akola
177	AKL-169	NBPGR, Akola
178	AKL-220	NBPGR, Akola
179	AKL-84	NBPGR, Akola
180	AKL-82	NBPGR, Akola
181	AKL-97	NBPGR, Akola
182	AKL-226	NBPGR, Akola
183	AKL-24	NBPGR, Akola
170	IC-73462	NBPGR, Akola
171	IC-118992	NBPGR, Akola
172	IC-53783	NBPGR, Akola
173	IC-73456	NBPGR, Akola
174	IC-73458	NBPGR, Akola
175	AKL-105	NBPGR, Akola
176	AKL-213	NBPGR, Akola
177	AKL-169	NBPGR, Akola
178	AKL-220	NBPGR, Akola
179	AKL-84	NBPGR, Akola
180	AKL-82	NBPGR, Akola

181	AKL-97	NBPGR, Akola
182	AKL-226	NBPGR, Akola
183	AKL-24	NBPGR, Akola
184	AKL-174	NBPGR, Akola
185	AKL-161	NBPGR, Akola
186	AKL-180	NBPGR, Akola
187	AKL-222	NBPGR, Akola
188	AKL-187	NBPGR, Akola
189	AKL-216	NBPGR, Akola
190	AKL-29	NBPGR, Akola
191	AKL-90	NBPGR, Akola
192	AKL-227	NBPGR, Akola
193	AKL-200	NBPGR, Akola
194	AKL-92	NBPGR, Akola
195	AKL-183	NBPGR, Akola
196	AKL-176	NBPGR, Akola
197	AKL-191	NBPGR, Akola
198	AKL-165	NBPGR, Akola
199	AKL-164	NBPGR, Akola
200	AKL-192	NBPGR, Akola

Table.2: Meteorological data of experimental site for the year 2015

Year	**Months**	**Temperature (°C)**	**Relative humidity (%)**	**Rainfall (mm)**
2015	January	21.32	61.03	0.59
	February	23.10	50.72	Nil
	March	25.34	58.70	2 mm (25.03.2015)
	April	25.87	66.55	Nil

Discovering per cent contribution of traits to the total variability

Among the six variables studied, proline content (21.03) had highest *per cent* contribution to the total variability possessed by physiological traits followed by leaf water potential (18.63), spad chlorophyll meter reading (18.61), relative water content (16.82), harvest index (13.30) and specific leaf area (11.58) (table 8 and figure 1). Our results are on par with the results of Mohammad and Sharif (2015) who reported that factor analysis indicated four independent factors explaining 75% of total variability in control condition and 78% variability in drought stress condition in mung bean. Srikanth *et al.*, (2017) has also reported similar findings on principal component analysis.

Table.3 Summary of augmented ANOVA for grain yield and physiological traits of germplasm accessions under drought condition

Sources of Variations	DF	HI	SCMR	LWP	PC	RWC	SLA	SYPP
Blocks (b)	4	247.54 **	396.55 **	1.17 **	470.90 **	423.68 *	4067.34 *	2.11 **
Entries (e) (Genotypes + Checks)	204	54.41 *	98.71 **	2.45 **	1707.90 **	425.40 **	4283.10 **	7.01 **
Checks	4	64.39 *	24.49	0.82 **	942.07 **	63.06	1924.20	3.76 **
Genotypes	199	53.01 *	79.58 *	2.33 **	1712.67 **	433.68 **	4294.15**	7.10 **
Checks vs Genotypes	1	293.20 **	4203.25 **	32.57 **	3822.09 **	227.32	11518.68**	0.42*
Error	16	19.57	31.14	0.03	1.48	130.64	1339.95	0.09

*Significant at P =0.05, ** Significant at P=0.01

Table.4 Correlation matrix (Pearson (n))

Variables	HI	SCMR	LWP	PC	RWC	SLA	SYPP
HI	1	0.70*	0.70*	0.74*	0.61*	0.34*	0.60*
SCMR	0.70*	1	0.80*	0.91*	0.79*	0.60*	0.62*
LWP	0.70*	0.80*	1	0.93*	0.77*	0.60*	0.61*
PC	0.74*	0.91*	0.93*	1	0.86*	0.67*	0.63*
RWC	0.61*	0.79*	0.77*	0.86*	1	0.66*	0.51*
SLA	0.34*	0.60*	0.60*	0.67*	0.66*	1	0.41*
SYPP	0.60*	0.62*	0.61*	0.63*	0.51*	0.41*	1

Values in bold* are significantly different at alpha=0.05

TP : Threshing % ; RWC : Relative water content (%); HI : Harvest index (%); SLA : Specific leaf area; SCMR : SPAD Chlorophyll meter reading; SYPP : Seed yield plant-1
LWP : Leaf water potential(Mpa); PC : Proline content (µg g−1)

Table.5 Kaiser-Meyer-Olkin measure of sampling adequacy

Traits	HI	SCMR	LWP	PC	RWC	SLA
KMO Values	0.94	0.90	0.82	0.81	0.93	0.94

Table.6 Eigen values of principal component analysis

Descriptives	F1	F2	F3	F4	F5	F6
Eigen value	4.59	0.68	0.28	0.22	0.18	0.02
Variability (%)	76.60	11.43	4.69	3.78	3.10	0.38
Cumulative %	76.60	88.03	92.73	96.51	99.61	100.00

Table.7 Factor loadings / component coefficient values of PCA

Traits	F1	F2	F3	F4	F5	F6
Harvest index	0.78	-0.51	-0.25	-0.22	-0.04	-0.006
Spad chlorophyll meter reading	0.92	-0.07	0.05	0.07	0.35	-0.04
Leaf water potential	0.92	-0.09	0.01	0.28	-0.21	-0.06
Proline content	0.98	-0.03	0.04	0.11	-0.004	0.12
Relative water content	0.87	0.16	0.34	-0.26	-0.08	-0.01
Specific leaf area	0.72	0.61	-0.30	-0.06	-0.007	-0.008

Table.8 Per cent contribution of the physiological traits to the total variability in PCA

Traits	F1	F2	F3	F4	F5	F6
Harvest index	13.30	39.20	22.89	23.06	1.33	0.18
Spad chlorophyll meter reading	18.61	0.81	1.13	2.75	68.46	8.22
Leaf water potential	18.63	1.24	0.09	36.43	25.82	17.77
Proline content	21.03	0.17	0.70	6.01	0.008	72.07
Relative water content	16.82	4.13	43.23	30.01	4.32	1.45
Specific leaf area	11.58	54.42	31.94	1.71	0.02	0.29

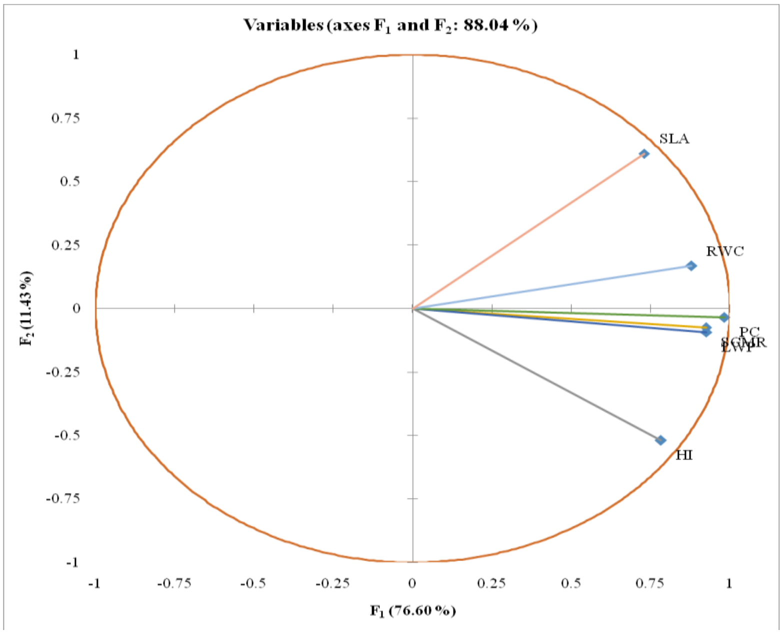


Figure.1 Loading plot of principal component analysis for six drought tolerant physiological variables

Principal component analysis identified only two factors out of six with eigenvalues more than or close to one contributing for more than 88.03 % of variability.Among the variables studied, variable proline content (11.91) had highest *per cent* contribution to the total variability followed by spad chlorophyll meter reading (10.80), leaf water potential (10.75), Relative water content (8.51) and specific leaf area (6.31) in green gram under drought condition.

Acknowledgement

Dr. Kanavi, M.S.P., thanks Director of Research, University of Agricultural Sciences, Bangalore for giving financial assistance to carry out the research work

References

Baroowa, B. and Gogoi, N. 2015. Changes in plant water status, biochemical attributes and seed quality of black gram and green gram genotypes under drought. *Int. lett. Nat. Sci.*, 42,1-12.

Clarke, J.M. and Townley-Smith, T.F. 1984, *Screening and selection techniques for improving drought tolerance. Crop Breeding: A Contemporary Basis.* Pergamon Press, Oxford, UK, *pp.*,137-162.

Dai, A. 2012. Increasing drought under global warming in observations and models. *Nat. Clim. Chang.*,3(52), 52-58.

Federer, W.T. 1956. *Augmented (or hoonuiaku) designs.* The Hawaiian Planters' Record. LV (2),191-208.

Graham, P. H. and Vance, C. P. 2003.*Legumes: importance and constraints to greater use.Plant Physiol.*,131, 872–877.

Hemavathy, T. A., Shunmugavalli, N. and Anand, G. 2014. Genetic variability, correlation and path coefficient studies on yield and its components in mung bean (*Vignaradiata*L. Wilczek). *Indian J. Agric. Res.*,38(4): 442-446.

Iqbal, Q., Saleem, M.Y., Hameed, A. and Asghar, M. 2014. Assessment of genetic diversity in tomato through agglomerative hierarchical clustering and principal component analysis. *Pakistan J. Bot.*, 46(5), 1865-1870.

Kabita Mishra., S. Panigrahi D. Sarangi. 2018. Evaluation of cluster front line demonstration in greengram crop. International Journal of Current Microbiology and Applied Sciences.,7(10), 3344-3350.

Kursar, T.A., Engelbrecht, B.M., Burke, A., Tyree, M.T., Ei Omari, B. 2009, Tolerance to low leaf water status of tropical tree seedlings is related to drought performance and distribution. *Funct. Ecol.*,23: 93-102.

Maréchaux, I., Bartlett, M.K., Sack, L., Baraloto, C., and Engel, J. 2015, Drought as predicted by leaf water potential at turgor loss point varies strongly across species within an Amazonian forest. *Functional Ecology.*,29, 1268-1277.

Mohammad, Ghanbariand Sharif, Mollashahi, Javan. 2015. Study of the response of mung bean genotypes to drought stress by multivariate analysis. *Int. J. Agric. Innov. Res.*, 3(4), 1298-1302.

Pooja, Bangar., Ashok, Chaudhury., Bhavana, Tiwari., Sanjay kumar., Ratnakumari. andKangila, Venkataramana, Bhat. 2019.Morphophysiological and biochemical response of mung bean [*Vignaradiata*(L.) Wilczek] varieties at different developmental stages under drought stress.*Turkish J. Biol.*,43(1), 58-69.

Rajeev Singh, R.,Singh, M.K.,Singh, A.K.,Singh, C., 2018. Pulses production in India: issues and elucidations. *Pharma.*

Innovation.,7(1), 10-13.

Reddy, A.A., 2009, Pulses production technology: status and way forward. *Econ. Political Wkly.*, 44(52), 73-80.

Rowland, M. Kamanga., Ernest, Mbegaand Patrick, Ndakidemi., 2018, Drought mechanisms in plants: physiological responses associated with water deficit stress in *Solanum lycopersicum*.*Adv. Crop Sci. Technol.*, 6(3), 1-8.

Sandhiya, V. and Saravanan, S. 2018.Genetic variability and correlation studies in green gram (*Vigna radiata* L. Wilczek). *Electron. J. Plant Breed.*,9(3), 1094-1099.

Shao, H.B., Chu, L.Y., Jaleel, C.A., Manivannan, P., Panneerselvam, R. and Shao, M.A. 2009. Understanding water deficit stress induced changes in the basic metabolism of higher plants biotechnologically and sustainably improving agriculture and the eco-environment in arid regions of the globe. *Crit. Rev. Biotechnol.*,29, 131-151.

Srikanth, Thippani.,Eshwari, K.B. and Bhave, M.H.V. 2017. Principal component analysis for yield components in green gram accessions (*Vigna radiata* L.). *Int. J. Pure App. Biosci.*, 5(4), 246-253.

Supratima M, Basu., Venkategowda, Ramegowda., Anujkumar and Andy Pereira. 2016. Plant adaptation to drought stress. *Faculty Rev.*,1554, 1-11.

Yaqub, M., Mahmood, T., Akhtar, M., Iqbal, M. M. and Ali, S. 2010.Induction of mung bean [*Vigna radiata* (L.) Wilczek] as a grain legume in the annual rice-wheat double cropping system.*Pakistan J. Bot.*,42,3125-3135.

How to cite this article:

Kanavi. M. S. P., N. Nagesha, G. Somu, B. T. Krishnaprasad and Rangaiah. S. 2020. Principal Component Analysis of Physiological Traits Governing Drought Tolerance in Germplasm Accessions of Green Gram [*Vigna radiata* (L.)]. *Int.J.Curr.Microbiol.App.Sci.* 9(03): 2943-2956. doi: https://doi.org/10.20546/ijcmas.2020.903.338