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Principal Component Analysis of Soybean Genotypes under Post Anthesis Drought Stress

Swati Saraswat* and Stuti Sharma

Department of Plant Breeding & Genetics, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, (M.P.), India

**Corresponding author*

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A B S T R A C T

In the present study, PCA performed for phenological and yield component traits revealed that out of sixteen, only four principal components (PCs) exhibited more than 1.00 eigen value, and showed about 74.79 % total variability among the traits studied under stress condition while under normal condition out of sixteen, only five principal components (PCs) exhibited more than 1.00 eigen value and showed about 77.84% variability among the traits studied. Scree plot explained the percentage of variance associated with each principal component obtained by drawing a graph between eigen values and principal component numbers. A high value of PC score of a particular genotype in a particular PC denotes high value for those variables. On the basis of PCA analysis under both stress as well as normal condition soybean genotypes namely; TGX 852-3D, SQL 89 and YOUNG have been selected for all the yield component traits under study and CAT 2082 and MACS 58 have been selected for phenological traits. This will help in the further improvement of genotypes for post anthesis drought stress breeding.

Introduction

Soybean (*Glycine max* L. Merill) also known as golden bean is a legume species native to East Asia. Presence of symbiotic bacteria let them fix atmospheric nitrogen. Soybean is economically the most important bean in the world, providing vegetable protein for millions of people and ingredients for hundreds of chemical products. The enhancement of lower productivity of the crop is one of the major challenges in front of the soybean researchers. The climatic variability leading to delay in monsoon, drought spells of various duration at different stages of crop particularly at seed fill stage is the main reason for soybean's low productivity in India (ICAR-IISR Annual Report 2018-19).

For the development and growth of plants adequate water is needed. Oxidative stress and a reduction in photosynthetic characteristics are the consequences of less than optimal water (Guo *et al.*, 2018). Drought affects soybean yield by affecting all stages of plant growth and development; from germination to flowering, and seed filling to development as well as seed quality (Siddique *et al.,* 2001; Manavalan *et al.,* 2009).

Occurrence of drought stress during vegetative stage can be compensated with rains during later part of crop growth, however drought at terminal growth stage especially during seed filling to seed maturity stage would cause severe yield loss which could not be recovered by any means (Sionit and Kramer, 1977; Hirasawa *et al.,* 1994; Saitoh *et al.,* 1999). Terminal drought stress in soybean causes gradual reduction in photosynthetic rate, followed by senescence of leaves and reduced seed size that finally results in reduced grain yields (Brevedan and Egli, 2003; Manavalan *et al.,* 2009). As several traits determine yield, we require a technique to identify and prioritize the important traits for effective selection. Principal component analysis, basically a well known data reduction technique identifies the minimum number of components, which can explain maximum variability out of the total variability (Anderson, 1972; Morrison, 1982) and also to rank genotypes on the basis of PC scores.

Materials and Methods

The present pot study was carried out at Glass House, Department of Plant Physiology, JNKVV, Jabalpur Madhya Pradesh during *kharif* 2018. The pot experiment was laid out in Completely Randomized Design with three replications. Thirty diverse genotypes of soybean were sown in pots inside glasshouse to screen them for drought tolerance and the genotypes were procured from ICAR-IISR (Indian Institute of Soybean Research), Indore and JNKVV released varieties from Department of Plant Breeding and Genetics, JNKVV, Jabalpur. Traits observed were days to flower initiation, days to full flowering, days to maturity, plant height at 30 days, plant height at maturity, number of nodes per plant, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of pod clusters per plant, number of seeds per pod, number of seeds per plant, biological yield per plant, harvest index and seed yield per plant on a sample of three random plants per replication whereas for days to flowering and days to maturity, data were taken on whole plot basis. PCA was calculated using Ingebriston and Lyon (1985) method.

Results and Discussion

Under stress condition

PCA performed for phenological and yield component traits in thirty soybean genotypes revealed that under stress condition, out of sixteen, only four principal components (PCs) exhibited more than 1 eigen value, and showed about 74.79 % total variability among the traits studied. So these four PCs were given due importance for further explanation (Table 1).

Scree plot laid out between Eigen value and principal component showed total variation between them (Fig. 1). First principal component recorded the highest variation 30.49% (PC1) followed by 22.15% (PC2), 12.14% (PC3) and 9.73% (PC4). Total variation of four PCs was recorded to be 77.48%. Semi curve line obtained after fourth PC with little variation observed in each PC indicated that maximum variation was found in PC1, therefore, selection of lines for traits under PC1 may be desirable.

Rotated component matrix (Fig. 2) revealed that the first principal component (PC1) which accounted for the highest variation (30.49%) was mostly related with traits such as number of primary branches per plant, number of pods per plant, number of pod clusters per plant, number of seeds per plant, biological yield per plant, 100 SW, harvest index, seed yield per plant. In second principal component (PC2) the traits days to flower initiation, days to 50 % flowering, days to maturity, number of nodes per plant, number of secondary branches per plant, while PC3 consisted of mainly two traits *viz*., plant height at 30 days and plant height at maturity whereas fourth principal component was related with number of seeds per pod (Table 2 and 3). On the basis of PCA, most of the important yield and yield attributing traits were present in PC1 and PC4. Rotated component matrix revealed that first four PCs are representing maximum variability (77.48%) hence, the traits falling to these four PCs may be given due importance in soybean drought breeding.

PC1 includes SQL 89 which had highest PC score followed by TGX 852-3D, YOUNG, JS 21-72, SQL 8, HARDEE and SQL 31 indicated that these genotypes possesses high values of traits *viz*., number of primary branches per plant, number of pods per plant, number of pod clusters per plant, number of seeds per plant, biological yield per plant, 100 SW, harvest index, seed yield per plant which are mainly yield attributing traits.

PC2 includes HARDEE which had highest PC score followed by CAT 3293, CAT 142, AGS 38, CAT 2082, MACS 58 AND YOUNG and it was mainly related with days to flower initiation, days to 50 % flowering, days to maturity, number of nodes per plant, number of secondary branches per plant.

The highest PC score was obtained by TGX 852-3D followed by SQL 89, SKY/AK-403, AMS 59, CAT 703, DAVIS and MACS 58 in PC3 for traits namely plant height at 30 days, plant height at maturity.

PC4 recorded the highest value for traits *viz*., number of seeds per pod by the genotypes AMS 26 A, CAT 2082, MACS 58, JS 21-73 and YOUNG (Table 4).

Based on top PC scores genotypes were categorized in the table 5.

Similar results were obtained by Iqbal (2008) for number of pods per plant, grain yield, biological yield per plant, 100 seed weight, harvest index, days to maturity and number of branches per plant and Ojo *et al.*, (2012) for number of pods per plant, pod length, pod yield per plant, 100 seed weight and seed yield per plant.

Under normal condition, out of sixteen, only five principal components (PCs) exhibited more than 1.00 eigen value and showed about 77.84% variability among the traits studied. Hence, these five principal components were given due importance for further explaination.

Scree plot had laid out between eigen value and principal component showed total variation between them (Fig. 3). First principal component recorded the highest variation 27.17% (PC1) followed by 19.59% (PC2), 13.24% (PC3), 9.69 % (PC4) and 7.774% (PC5). Total variation of five PCs was recorded to be 77.48%. Semi curve line obtained after fifth PC with little variation observed in each PC indicated that maximum variation was found in PC1; therefore, selection of lines for traits under PC1 may be desirable (Table 6).

Rotated component matrix revealed that the first principal component (PC1) which accounted for the highest variation (27.17%) was mostly related with traits such as number of pods per plant, number of pod clusters per plant, number of seeds per pod, number of seeds per plant, biological yield per plant, harvest index, seed yield per plant. In second principal component (PC2) the traits *viz*., days to flowering, days to 50% flowering, days to maturity, number of secondary branches per plant. While PC3 consisted of mainly two traits *viz*., plant height at 30 days and plant height at maturity. Fourth principal component (PC4) was related with 100 SW. PC5 consisted of number of nodes per plant and number of secondary branches per plant (Table 7 and 8).

On the basis of PCA, most of the important yield and yield attributing traits were present in PC1 and PC5. Rotated component matrix revealed that first five PCs are representing maximum variability (77.48%) hence, the traits falling to these five PCs may be given due importance in soybean breeding.

TGX 852-3D had the highest PC score followed by CAT 2082, CAT 3293, DAVIS, SQL 89, JS 20-29 in PC1 indicated that these genotypes possesses high values of traits *viz*., number of pods per plant, number of pod clusters per plant, number of seeds per pod, number of seeds per plant, biological yield per plant, harvest index, seed yield per plant which are mainly yield attributing traits.

The highest PC score of CAT 142 followed by CAT 3293, AGS 38, MACS 58, CAT 649, CAT 2082, CAT 703, HARDEE, SQL 88 and YOUNG in PC2 was mainly related with days to flowering, days to 50% flowering, days to maturity, number of secondary branches per plant.

The highest PC score was obtained by AMS 59 followed by YOUNG, JS 21-17, AMS 19 B, TGX 852-3D, JS 20-29 and MACS 58 in PC3 for traits namely plant height at 30 days and plant height at maturity (Fig. 4).

Table.1 Eigen values, percentage of total variation and cumulative percentage for corresponding sixteen traits under Stress condition

Traits	Principal component (PC)	Eigen value	Variability (%)	Cumulative %
DFI	PC1	4.879	30.495	30.495
DFF	PC2	3.545	22.158	52.653
DM	PC3	1.986	12.414	65.067
Pl Ht. at 30 DAS	PC4	1.557	9.730	74.797
Pl Ht. at maturity	PC5	0.780	4.873	79.670
NNP	PC6	0.726	4.535	84.204
NPBP	PC7	0.651	4.069	88.273
NSBP	PC8	0.543	3.392	91.666
NPP	PC9	0.514	3.213	94.879
NPCP	PC10	0.290	1.814	96.693
NS/ pod	PC11	0.249	1.558	98.251
NSP	PC12	0.124	0.776	99.026
BY	PC13	0.095	0.592	99.618
100 SW	PC14	0.038	0.240	99.858
HI	PC15	0.019	0.119	99.977
SYPP	PC16	0.004	0.023	100.00

Table.2 Principal Components for 16 phenological and yield contributing traits of soybean genotypes under stress condition

Traits	Principal Components			
	PC1	PC2	PC3	PC4
DFI	0.050	**0.737**	-0.207	-0.207
DFF	0.127	**0.762**	-0.282	-0.282
DM	-0.155	**0.662**	-0.303	-0.303
Pl Ht. at 30 DAS	-0.080	-0.102	**0.916**	**0.916**
Pl Ht. at maturity	-0.121	0.505	**0.691**	**0.671**
NNP	0.112	**0.667**	0.132	0.132
NPBP	**0.470**	0.411	0.001	0.001
NSBP	0.203	**0.582**	0.065	0.065
NPP	**0.874**	0.242	0.222	0.222
NPCP	**0.878**	0.167	0.193	0.193
NS/ pod	-0.030	-0.552	0.003	0.003
NSP	**0.790**	-0.285	0.322	0.322
BY	**0.844**	0.086	-0.180	-0.180
100 SW	**0.599**	-0.436	-0.453	-0.453
HI	**0.699**	-0.270	0.000	0.000
SYPP	**0.906**	-0.150	-0.074	-0.074

Table.3 Interpretation of rotated component matrix for the traits having values >1 in each PCs under stress condition

	PC 1	PC 2	PC 3	PC 4
TRAITS	No of primary branches per plant	Day to flowering	Plant height at 30 days	No of seeds per pod
	No of pods per plant	Days to 50 % flowering	Plant height at 60 days	-
	No of pod clusters per plant	Days to maturity	-	-
	No of seeds per plant	No of nodes per plant	-	-
	Biological yield per plant	No of secondary branches per plant	-	-
	100 seed weight	-	-	-
	Harvest Index	-	-	-
	Seed yield per plant	-	-	-

Table.4 PCA scores of soybean genotypes under Stress condition

S.No.	Genotypes	PC1	PC2	PC3	PC4
1	JS 20-29	0.206	0.117	0.937	0.362
2	JS 20-69	-0.168	-0.400	-1.801	-0.429
3	JS 20-98	-1.406	-0.416	-0.344	0.746
4	JS 97-52	0.427	0.382	-0.157	0.383
5	DAVIS	0.401	0.174	**1.288**	0.368
6	YOUNG	**3.228**	**1.168**	-1.580	**1.197**
7	JS 21-17	0.837	-1.685	0.489	0.092
8	AMS MB 518	-0.253	-1.134	-0.253	0.501
9	TGX 852-3D	**3.403**	-1.552	**3.516**	0.831
10	MACS 58	-0.524	**1.712**	**1.120**	**1.729**
11	SKY/AK-403	-2.231	-0.901	**2.106**	-0.646
12	HARDEE	**2.280**	**4.348**	0.436	-0.303
13	JS 21-73	-0.776	-1.483	-0.441	**1.373**
14	CAT 142	-1.228	**3.429**	0.294	0.561
15	CAT 649	-1.708	-1.496	0.601	0.877
16	CAT 703	-1.970	0.589	**1.405**	0.184
17	CAT 3293	0.839	**4.112**	-0.567	0.009
18	CAT 2082	0.965	**2.226**	-1.376	**2.145**
19	AGS 38	-2.204	**2.617**	-1.349	-0.573
20	AMS 59	-4.168	-0.152	**1.516**	-1.845
21	AMS 19 B	-3.200	0.097	0.813	-2.315
22	AMS 26 A	-1.692	-2.904	-0.185	**2.602**
23	AMS 148	0.177	-0.417	0.117	0.478
24	SQL 8	**2.605**	-3.070	-2.128	-0.705
25	SQL 31	**2.197**	0.996	-1.380	-3.156
26	SQL 88	-0.840	-0.173	-1.214	-0.520
27	SQL 89	**6.097**	-0.934	**2.670**	-1.805
28	SQL 106	-2.487	-1.374	-1.085	-0.715
29	JS 21-71	-1.462	-1.360	-1.090	-1.197
30	JS21-72	**2.654**	-2.516	-2.359	-0.225

Table.5 List of selected genotypes in each principal component under Stress condition

PC1	PC2	PC3	PC4
SQL 89	**HARDEE**	**TGX 852-3D**	**AMS 26 A**
TGX 852-3D	**CAT 3293**	**SQL 89**	**CAT 2082**
YOUNG	**CAT 142**	**SKY/AK-403**	**MACS 58**
JS21-72	**AGS 38**	**AMS 59**	**JS 21-73**
SQL 8	**CAT 2082**	**CAT 703**	**YOUNG**
HARDEE	**MACS 58**	**DAVIS**	
SQL 31	**YOUNG**	**MACS 58**	

Table.6 Eigen values, percentage of total variation and cumulative percentage for corresponding sixteen traits in soybean genotypes under Normal condition

Traits	Principal component (PC)	Eigen value	Variability (%)	Cumulative %
DFI	PC1	**4.348**	**27.177**	**27.177**
DFF	PC2	3.135	19.593	46.770
DM	PC3	2.120	13.248	60.019
Pl Ht. at 30 DAS	PC4	1.551	9.691	69.710
Pl Ht. at maturity	PC5	1.244	7.774	77.845
NNP	PC6	0.841	5.257	82.742
NPBP	PC7	0.748	4.678	87.420
NSBP	PC8	0.561	3.508	90.928
NPP	PC9	0.451	2.817	93.744
NPCP	PC10	0.413	2.580	96.325
NS/ pod	PC11	0.241	1.505	97.829
NSP	PC12	0.173	1.084	98.914
BY	PC13	0.068	0.424	99.338
100 SW	PC14	0.064	0.397	99.735
HI	PC15	0.037	0.230	99.965
SYPP	PC16	0.006	0.035	100.00

Table.7 Principal Components for 16 phenological and yield contributing traits of soybean genotypes under normal condition

Traits	Principal Components				
	PC1	**PC2**	**PC3**	**PC4**	**PC5**
DFI	0.322	**0.690**	-0.009	0.449	-0.060
DFF	0.394	**0.653**	-0.113	0.496	-0.221
DM	0.039	**0.675**	-0.345	-0.069	0.006
Pl Ht. at 30 DAS	0.071	-0.042	**0.917**	-0.089	0.069
Pl Ht. at maturity	0.078	0.389	**0.815**	0.158	0.034
NNP	0.394	0.451	-0.004	-0.400	**0.500**
NPBP	-0.225	0.352	-0.261	0.223	**0.748**
NSBP	-0.136	**0.634**	0.089	-0.272	0.258
NPP	**0.864**	0.119	-0.190	-0.277	-0.150
NPCP	**0.746**	0.253	-0.212	-0.410	-0.171
NS/ pod	**0.436**	-0.426	0.255	0.374	0.366
NSP	**0.882**	-0.231	0.045	-0.112	0.028
BY	**0.571**	0.224	0.083	0.427	-0.163
100 SW	-0.055	-0.454	-0.494	**0.417**	0.149
HI	**0.710**	-0.486	-0.078	-0.063	0.242
SYPP	**0.865**	-0.296	0.046	0.153	0.124

Table8 Interpretation of rotated component matrix for the traits having values >01 in each PCs under Normal condition

	PC 1	PC 2	PC 3	PC 4	PC5
TRAITS	Number of pods per plant	Days to flowering	Plant height at 30 days	100 seed weight	Number of nodes per plant
	Number of pod clusters per plant	Days to 50% flowering	Plant height at 60 days	-	Number of secondary branches per plant
	Number of seeds per pod	Days to maturity	-	-	-
	Number of seeds per plant	Number of secondary branches per plant	-	-	-
	Biological yield per plant	-	-	-	-
	Harvest Index	-	-	-	-
	Seed yield per plant	-	-	-	-

Table.9 PC scores of soybean genotypes under Control condition

S.No.	Genotypes	PC1	PC2	PC3	PC4	PC5
1	JS 20-29	**1.424**	-0.588	**1.443**	0.359	0.131
2	JS 20-69	-0.331	0.228	-0.048	**1.073**	**1.735**
3	JS 20-98	0.182	0.393	0.527	**1.213**	**2.447**
4	JS 97-52	-0.516	-0.407	0.236	0.358	0.206
5	DAVIS	**3.182**	-0.465	-0.561	-3.481	**1.019**
6	YOUNG	-0.674	**1.039**	**2.640**	**2.308**	-1.150
7	JS 21-17	0.986	-1.924	**2.338**	**1.887**	0.433
8	AMS MB 518	-0.472	-0.836	0.200	-0.554	0.464
9	TGX 852-3D	**6.185**	-3.185	**1.714**	-1.521	-0.020
10	MACS 58	-0.485	**1.947**	**1.288**	0.598	**1.460**
11	SKY/AK-403	-0.801	-1.114	0.919	-1.448	-1.086
12	HARDEE	0.239	**1.123**	-0.529	**1.554**	-0.276
13	JS 21-73	0.769	-2.648	-0.150	0.249	-1.160
14	CAT 142	0.903	**3.431**	0.580	-0.236	-0.788
15	CAT 649	0.486	**1.777**	0.240	-1.106	-0.489
16	CAT 703	-0.787	**1.323**	0.277	-1.231	-0.269
17	CAT 3293	**3.232**	**3.331**	-1.428	0.294	-2.428
18	CAT 2082	**3.576**	**1.573**	-1.978	0.810	-0.388
19	AGS 38	-2.032	**3.045**	-1.244	-0.638	0.502
20	AMS 59	-3.804	0.223	**2.867**	-2.118	-0.117
21	AMS 19 B	-3.108	0.698	**1.892**	-0.935	-1.385
22	AMS 26 A	-0.388	-1.255	-0.130	0.876	**1.455**
23	AMS 148	0.153	-0.506	0.756	0.436	0.325
24	SQL 8	-2.515	-2.291	-2.585	-0.369	0.846
25	SQL 31	-1.475	-0.043	-2.406	-1.191	0.829
26	SQL 88	-0.075	**1.074**	-0.840	0.461	**1.327**
27	SQL 89	**1.892**	-0.501	-1.559	**1.121**	-0.039
28	SQL 106	-1.858	0.112	-1.607	-0.369	-0.115
29	JS 21-71	-2.065	-2.470	-1.321	**1.236**	-2.048
30	JS21-72	-1.824	-3.086	-1.532	0.364	-1.418

Table.10 List of selected genotypes in each principal component under Normal condition

S.No.	PC1	PC2	PC3	PC4	PC5
1	TGX 852 -3D	CAT 142	AMS 59	YOUNG	JS 20-98
2	CAT 2082	CAT 3293	YOUNG	JS 21-17	JS 20-69
3	CAT 3293	AGS 38	JS 21-17	HARDEE	MACS 58
4	DAVIS	MACS 58	AMS 19 B	JS 21-71	AMS 26 A
5	SQL 89	CAT 649	TGX 852-3D	JS 20-98	SQL 88
6	JS 20-29	CAT 2082	JS 20-29	SQL 89	DAVIS
7		CAT 703	MACS 58	JS 20-69	
8		HARDEE			
9		SQL 88			
10		YOUNG			

Fig.1 Scree plot of principal component analysis of soybean genotype between eigen value and principal components under stress condition

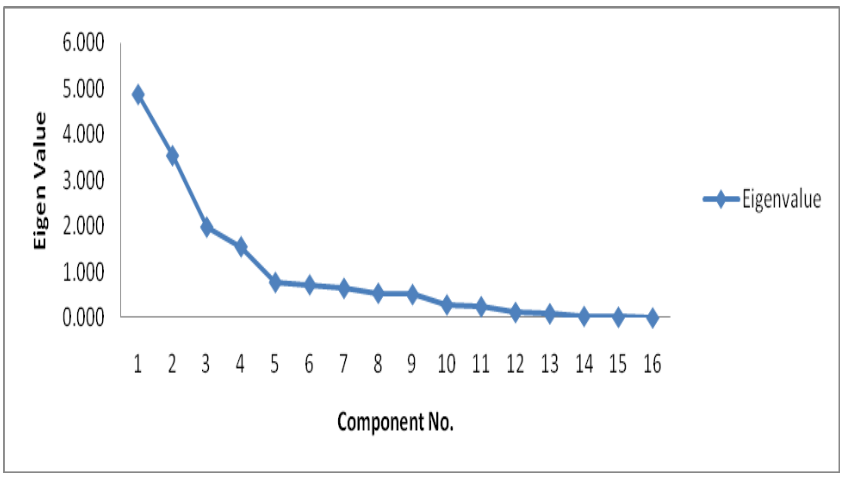


Fig.2 Phenlogical and yield traits of soybean genotypes under stress condition shown in Bar Diagram

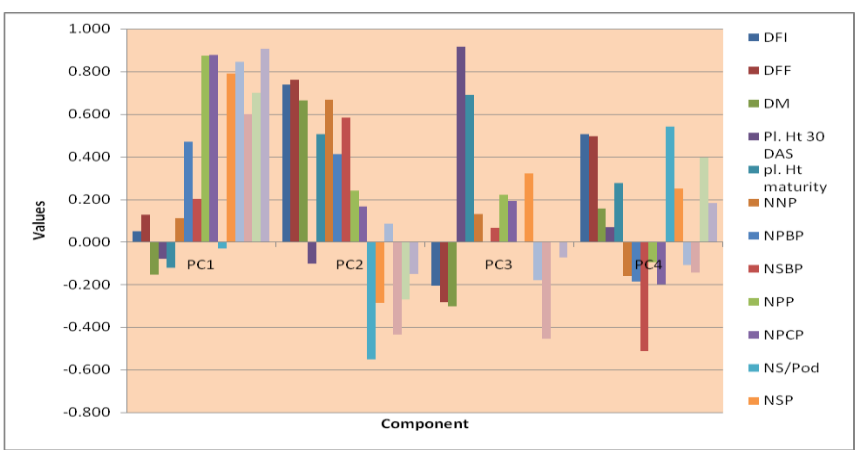


Fig.3 Scree plot of principal component analysis of soybean genotype between eigen value and principal components under normal condition

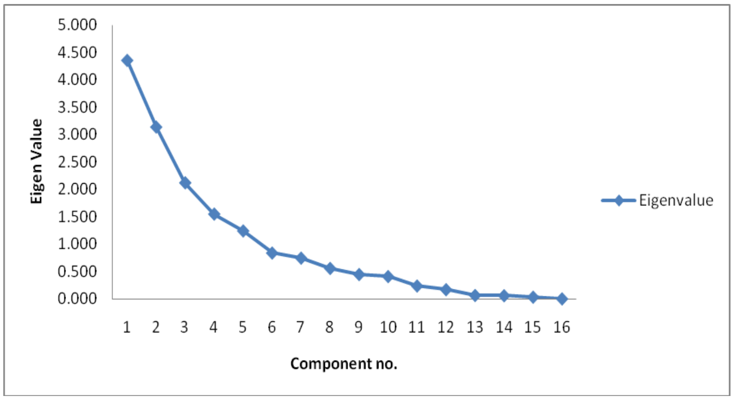
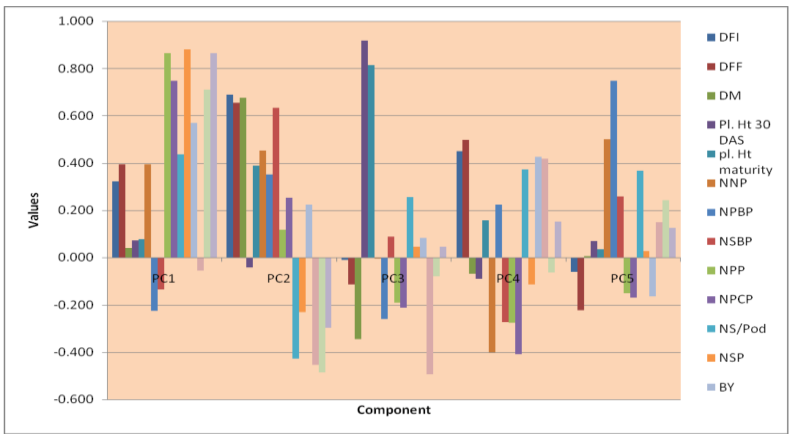


Fig.4 Phenlogical and yield traits of soybean genotypes under normal condition shown in Bar Diagram



PC scores in PC4 were recorded the highest value for traits *viz*., 100 SW. by the genotypes YOUNG, JS 1-17, HARDEE, JS 21-71, JS 20-98, SQ 89 and JS 20-69.

However, JS 20-98, JS 20-69, MACS 58, AMS 26 A and SQL 88 had the highest PC scores in PC5 for number of nodes per plant and number of secondary branches per plant.

Based on top PC scores genotypes were categorized in the Table 10.

Similar results have been found by Badkul *et al.*, 2014 for plant height, number of branches per plant and yield per plant and by Dubey *et al.*, 2018. for days to 50% flowering, days to maturity, plant height, number of branches per plant, number of nodes per plant, number of pods per plant, number of pods per node, number of seeds per plant, biological yield per plant and seed yield per plant.

From the above discussion under stress condition it is clear that SQL 89 holds the first position followed by HARDEE and TGX 852-3D on the basis of PC score in all principal components. When we considered the entire PC with PC scores and character basis then SQL 89 ranked first because it is present in PC1 as well as in PC3. SQL 89 contributes maximum character because most of the yield related traits are present in PC1. TGX 852-3D Present in PC1 and PC3 and contributes maximum character as yield related traits are present maximum in PC1 and along with that plant height at 30 days and maturity are included in PC3.YOUNG is present in PC1, PC2 and PC4. Maximum yield contributing traits are present in PC1, days to flowering, 50% flowering, days to maturity are included in PC2 while 100 SW is included in PC4.MACS 58 is present in PC2, PC3 in which phonological traits are present and PC4 which has 10 SW. Similar is the case with CAT 2082 which is present in PC2 containing phonological traits and PC4 containing 100 seed weight.

Under normal condition TGX 852-3D holds the first position followed by CAT 142 and AMS 59 on the basis of PC score in all principal components. When we considered the entire PC with PC scores and character basis then TGX 852-3D ranked first because it is present in PC1 and PC3 both i.e. yield related traits along with plant height at 30 days and maturity. SQL 89 is present in PC1and PC4 comprising of yield related traits and 100 seed weight respectively. YOUNG is present inPC2, PC3 and PC5 comprising of phonological traits and 100 seed weight respectively. MACS 58 is present in PC2, PC3 and PC5 comprising of all the phenological traits. CAT 2082 is present in PC1 and PC2 which comprises of both yield related and phenological traits.

In conclusion a high value of PC score of a particular advanced line in a particular PC denotes high value for those variables. On the basis of PCA analysis under both stress as well as normal condition soybean genotypes namely; TGX 852-3D, SQL 89 and YOUNG have been selected for yield contributing traits under study and CAT 2082 and MACS 58 have been selected for phenological traits. This will help in the further improvement of genotypes for post anthesis drought stress breeding.

References

Anderson T W. 1972. An introduction to multivariate Analysis. Wiley Eastem Pvt Ltd. New Delhi.

Annual report. ICAR-IISR. 2018-19.

Ashley DA and Ethridge WJ. 1978. Irrigation Effects on vegetative and reproductive development of three soybean cultivars. Agronomy Journal. Vol. 70 No. 3, p. 467-471.Asiatic Society of Bengal 25: 301- 77.Association, and Divergence in Soybean Mutants. The Scientific World.

Badkul, A., A. N. Shrivastava, R. Bisen and S. Mishra (2014). Study of principal components analyses for yield contributing traits in fixed advanced generations of soybean [Glycine max (L.) Merrill]. Soybean Research, 2 : 44-50.

Brevedan RE, Egli DB (2003) Short periods of water stress during seed filling, leaf senescence, and yield of soybean. Crop Sci 43:2083-2088.

Dubey N, Avinashe HA and Shrivastava AN. 2018. Principal component analysis in advanced genotypes of soybean over seasons. Plant Archives. 18 (1): 501-506.

Guo Y., Tian S., Liu S., Wang W., Sui N. (2018). Energy dissipation and antioxidant enzyme system protect photosystem II of sweet sorghum under drought stress. Photosynthetica 56, 1–12.

Hirasawa T, Tanaka K, Miyamoto D, Takai M, Ishihara K (1994) Effects of preflowering soil moisture deficit on dry matter production and eco-physiological characteristics in soybean plants under drought conditions during grain filling. Japan J Crop Sci 63:721-730

Ingebriston S E and Lyon R J P. 1985. Principal components analysis of muti-temporal image pairs: International Journal of Remote sensing. Volume 6: 687-696.

Iqbal Zafar, Muhammad Arshad, Muhammad Ashraf, Mahmood Tariq and Waheed Abdul. 2008. Valuation of soybean (Glycine max (L.) Merill) germplasm for some important morphological traits using multivariate analysis. Pakistan Journal of Botany 40(6): 2323-2328.

Manavalan LP, Guttikonda SK, Tran LP, Nguyen HT (2009) Physiological and molecular approaches to improve drought resistance in soybean. Plant and Cell Physiol 50(7):1260–1276.

Morrison DE. 1982. Multivariate Statistical Methods (2nd ed. 4th print, 1987), McGraw hill Kogakusta Ltd.

Ojo DK, Ajayi AO and Oduwaye OA. 2012. Genetic relationships among soybean accessions based on morphological and RAPDs techniques. Pertanika joutnal of Tropical Agricultural Science 35(2): 237-48.

Saitoh K, Mahmood T, Kurada T (1999) Effect of moisture stress at different growth stages on flowering and pod set in determinate and indeterminate soybean cultivars. Japan J Crop Sci 68:537-544.

Siddique KHM, Regan KL, Tennant D, Thomson BD (2001) Water use and water use efficiency of cool season grain legumes in low rainfall Mediterranean-type environments. European J Agron 15(4): 267-280

Sionit N, Kramer PJ (1977) Effect of water stress during different stages of growth of soybean. Agron J 69:274-278.

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