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SELECTION OF SOYBEANS FOR ADAPTATION THROUGH PRINCIPAL COMPONENT ANALYSIS UNDER DIFFERENT CLIMATIC FACTORS AT SEEDLING STAGE

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Abstract

Soybean (*Glycine max* L.) is known as "Golden Beans" that is also called "meat that grows on plant". It is a climate sensitive crop so adaptation under different climatic regimes is a permanent solution. The crucial factors for its adaptation are temperature, photoperiod and water. The right combination of these climatic factors allows soybean to avoid unwanted conditions for germination, growth and to maximize the yield. The present study was focused on selection of soybeans for adaptation under different climatic regimes. Three separate experiments were conducted. Eighty accessions were screened under three different water treatments (T_0= 100% water holding capacity, T_1= 60% water holding capacity and T_2= 40% water holding capacity) photoperiod treatments (T_0 = 10 hours, T_1= 11 hours and T_2 = 13) and temperature treatments (T_0= 30°C, T_1= 35°C and T_2= 40°C) using Split Plot with Completely Randomized Design. Data of seedlings for water, temperature and photoperiod related traits were recorded. The recorded data were subjected analysis of variance, mean values (photoperiod) and Principal Component Analysis (water and temperature). Five best accessions (common in water, temperature and photoperiod experiments) were selected. Selected accessions can be used as potential parents for the development of breeding material and may be further evaluated under different climatic conditions to study their worth for adaptation.

Key words: Selection, Soybean accessions, Water, Temperature and Photoperiod.

Introduction

The demand for energy and protein rich food is high in developing countries. Soybean being the most important source of both vegetable oil and protein concentrates occupies premier position among many crops. Soybean (*Glycine max* L.) is known as "Golden Beans" that is also called "meat that grows on plant" because its seed contains 40% protein on an average (Ali *et al*., 2013). Food and agriculture organization (FAO) classified it as an oilseed crop rather than a pulse crop due to extensive use of its oil i.e. 16-23% in its seed (Hamayun *et al*., 2010; Amjad, 2014). Bottleneck in production of soybean are; sensitivity to climate changes, competition with major crops and unavailability of climate specific varieties (Ali *et al*., 2013). Soybean is a climate sensitive crop so adaptation of various accessions under changing climate is a permanent solution. The crucial factors for its adaptation under different climatic conditions are temperature, photoperiod and water. The right combination of these climatic factors allows soybean to avoid unwanted conditions for germination, growth and to maximize the yield. Response of a crop to temperature, water and photoperiod defines its adapted areas (Summerfield *et al*., 1989). Temperature effects on soybean germination as with 1ºC increase in temperature, there is 99% decrease in germination (Tayagi & Tripathi, 1983; Khalil *et al*., 2010). At about 30°C the components of yield of soybean are not significantly affected but further rise in temperature i.e. 35°C may lead to significant and negative reduction from R_1 to R_5 and R_1 to R_2 stages of growth (Puteh *et al*., 2013). High temperature reduces quality of soybean seed developed at different positions on the plant (Khalil *et al*., 2010). Li *et al*., (2020) and Thanacharoenchanaphas & Rugchati (2011) reported that variability in water requirement and temperature during reproductive stages of soybean can reduce its seed yield. However other reports in the past revealed that seeds/pod remained least affected by temperature (Huxley *et al*., 1976; Sionit *et al*., 1987; Baker *et al*., 1989). Flowering induction in soybean is inhibited by intensity of light greater than 5.3 lux (Borthwick & Parker, 1938). Response of soybean lines is different to photoperiod. It varies according to critical day length at which formation of flower is initiated. Early maturing lines of soybean are less sensitive to day length than late maturing (Kenworthy *et al*., 1989). During pod fill stage when soybean is exposed to long day length, nitrogen remobilization rate from leaves, seed size, pod growth rate and yield are reduced (Cure *et al*., 1982). The physiological response of plant to low availability of water is complex and involves adaptive and deleterious changes (Chaves *el al*., 2002). Germination of soybean can proceed under water tension of -6.6 bars. Excess water reduces the yield by 20 to 25% on an average. But depending on the plant's development stage this loss can exceed 50% (Setter & Belford, 1990). It can be lethal for the plants because aerobic respiration declines resulting in dramatic decrease in ions transport and uptake (Vartapetian & Jackson 1997). There is variation for critical soil water content at which water use begin to decline in soybean indicating that different genotypes has different decisions about how to responds to reduced availability of water (Hufstetler *et al*., 2007).

Selection of available germplasm under variable climatic conditions is important for the detection of suitable lines (Baraskar *et al*., 2014). It points out some advantages i.e. relatively inexpensive, parameters can be easily studied and trails can be done in short time (Tischler *et al*., 1991). It is very helpful to access large number of genotypes in controlled conditions (Rai *et al*., 2011). Identification of desirable lines and success of breeding method depend on availability of reproducible and robust selection protocol. Due to climatic factors and soil heterogeneity, selection at field level is relatively difficult which can influence physiological processes (Koyama *et al*., 2001; Flowers 2004; Mamnabi *et al*., 2020).

Considering all the factors mentioned above, selection of soybeans under different levels of water, temperature and photoperiod for adaptation at seedling stage, became primary focus of the research.

Materials and Methods

Collection of germplasm and its source: Germplasm of soybean was collected from Bio-Resources Conservation Institute, National Agricultural Research Centre, Islamabad. Three experiments were conducted separately. Eighty accessions were screened under three different water, photoperiod and temperature treatments using Split Plot with Completely Randomized Design with three replications to select best common accessions (Table 1).

Screening of soybeans under normal and water stress treatments: Experiment was laid out in the Sunflower Research Laboratory of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. Water holding capacity of mixture of sand and soil was measured by using percolation method. Three funnels were taken and placed on the graduated cylinders. Filter papers were put in each funnel. Three samples of 100 grams of soil were taken and put it on the funnel's filter paper. One hundred ml of water was poured over the soil slowly on the sample in each funnel. Water trickled down into the soil as the soil got wet. Quantity of poured water was measured after 2 hours. Three different water stress levels were used (100%, 60% and 40% water holding capacity). Following formulae were used for the calculation of water holding capacity of stress levels.

T_0 (Control) = 100% water holding capacity = (Quantity of water poured/ Quantity of water collected after percolation)/2

T_1= 60% water holding capacity = (100% water holding capacity ×40)/100

T_2= 40% water holding capacity = (100% water holding capacity ×60)/100

Three plastic cups (6.5cm×10cm) of each accession per replication per treatment were filled with measured quantity of mixture of sand and soil. Two seeds of each accession per treatment per replication were sown in cups. 33ml, 20ml and 15ml water was measured with measuring cylinder and watering was done after every two days according to 100%, 60% and 40% field capacity respectively. Growth of seedlings was observed daily. After 21 days, seedlings were taken and data of seedlings for water related traits i.e. root and shoot length (in cm with measuring scale), fresh and dry root and shoot weight (in g by using weight balance Setra-BL 4105), seedling emergence rate (Seedlings with length of 5mm were selected and length was measured for consecutive three days. Average was taken to calculate seedling emergence rate), germination percentage (number of germinated seeds with radical extension of >3mm/total seeds sown)×100, leaf area (leaf width (mm) × leaf length (mm), chlorophyll content (in mg by using chlorophyll meter SPAD-502) and leaf water content (in % according to Barr and Weatherley, 1962) were recorded.

Table 1. Soybean accessions used in the experiment.

Sr. No.	Accession	Sr. No.	Accession	Sr. No.	Accession	Sr. No.	Accession
1.	17415	21.	17439	41.	24562	61.	24585
2.	17416	22.	17440	42.	24563	62.	24587
3.	17418	23.	17441	43.	24564	63.	24588
4.	17419	24.	17442	44.	24565	64.	24589
5.	17420	25.	17444	45.	24566	65.	24590
6.	17421	26.	17445	46.	24567	66.	24593
7.	17423	27.	17446	47.	24569	67.	24594
8.	17424	28.	17447	48.	24571	68.	24595
9.	17427	29.	17449	49.	24572	69.	24596
10.	17428	30.	17450	50.	24573	70.	24597
11.	17429	31.	17451	51.	24574	71.	24598
12.	17430	32.	17452	52.	24576	72.	24599
13.	17431	33.	17458	53.	24577	73.	24600
14.	17432	34.	17459	54.	24578	74.	24601
15.	17433	35.	17460	55.	24579	75.	24602
16.	17434	36.	17461	56.	24580	76.	24603
17.	17435	37.	17462	57.	24581	77.	24604
18.	17436	38.	17463	58.	24582	78.	24606
19.	17437	39.	24560	59.	24583	79.	24608
20.	17438	40.	24561	60.	24584	80.	24618

Screening of soybeans under normal and temperature stress treatments: Experiment was laid out in the growth chamber of Department of Seed Science and Technology, University of Agriculture, Faisalabad. Same accessions of soybean (Table 1) were screened for three temperature treatments (**T_0** (Control) = 30°C, **T_1**= 35°C and **T_2**= 40°C) in three FDM Della Marca growth chambers. Two seeds of each accession per treatment per replication were sown in seedling trays using split plot with Completely Randomized Design. Three seedling trays per treatment were kept in growth chambers. Humidity of 60% was maintained in each growth chamber. Duration and intensity of light were 10 hours and 5.3lux respectively during experiment. 20ml of water per accession per replication per treatment was applied after every two days. Growth of seedlings was observed daily. After 21 days, seedlings were taken and data of seedlings for temperature related traits i.e. root and shoot length (cm), fresh and dry root and shoot weight (g), seedling emergence rate, germination percentage, leaf temperature (in °C with temperature gun), proline content (in µg according to bates *et al*., 1973) and electrolyte membrane leakage (in % according to Lutts *et al*., 1996).

Screening of soybeans under normal and photoperiod stress treatments: Similar procedure (screening of soybeans under normal and temperature stress treatments) was repeated to screen same accessions (Table 1) at seedling stage for three photoperiod treatments (**T_0** (Control)= 10 hours, **T_1**= 11 hours and **T_2** = 13 hours). Temperature and intensity of light in each growth chamber was maintained at 30°C and 5.3lux respectively during experiment. After 21 days, seedlings were taken and data for photoperiod related trait (number of nodes/seedling) were recorded.

Recorded data were subjected to analysis of variance following Steel *et al*., (1997) Mean comparison for photoperiod related trait and Principal Component Analysis for temperature and water experiments was used to screen best common accessions followed by Gabriel *et al*., (1971) as Principal Component Analysis cannot be used for single trait.

Results

Analysis of variance

Analysis of variance of soybeans under normal and water stress treatments: All water related traits i.e. chlorophyll content, leaf area, dry root weight, dry shoot weight, fresh root weight, fresh shoot weight, root length, shoot length, leaf water content, seedling emergence rate and germination percentage showed significant differences among accessions and interaction of water treatments and accessions. Among treatments, dry root weight and leaf water content showed significant differences (Table 2).

Analysis of variance of soybeans under normal and temperature stress treatments: All temperature related traits i.e. electrolyte membrane leakage, dry root weight, dry shoot weight, fresh root weight, fresh shoot weight, root length, shoot length, leaf temperature, proline content seedling emergence rate and germination percentage showed significant differences among accessions, treatments and interaction of temperature treatments and accessions (Table 3).

Analysis of variance of soybeans under normal and photoperiod stress treatments: Photoperiod related trait i.e. number of nodes/ seedling showed significant differences among accessions, treatments and interaction of treatments and accessions (Table 3, last column). Therefore, this genetic variability can be further used for adaptability and yield improvement programme in soybean.

Principal component analysis

Principal component analysis of soybeans under normal and water stress treatments: In any breeding program, when many traits and many accessions are involved principal component analysis is helpful in the selection. In present study, all the factors had Eigen value less than 1 except root and shoot length under all the treatments. Contribution of root and shoot length to total variation was 71.07% and 12.02% respectively for PCA1 (T_0= 100% water holding capacity) (Fig. 1) while, its contribution was 67.53% and 16.99% respectively for PCA2 (T_1= 60% water holding capacity) (Fig. 2). Among total variation contribution of these traits was 78.61% and 9.85% respectively for PCA3 (T_2= 40% water holding capacity) (Fig. 3).

Graphs for PCA1 (T_0), PCA2 (T_1) and PCA3 (T_2) are presented in (Figs. 4, 5 and 6) respectively. Accessions 24573, 24583, 24602, 24566, 24601, 17446, 17445, 17418 and 24618 fall in Quadrate I so these accessions were considered as best water tolerant for PCA1(T_0). Selected accessions showed more variation for chlorophyll content, leaf area and leaf water content as these are shown by the vectors in graph. Accessions 24593, 24595, 24589 and 24585 fall in Quadrate III so these accessions are considered as water sensitive for PCA1 (T_0). Selected accessions were poor for all the studied water related traits.

Accessions 24562, 24566, 24567, 24595, 24589 and 24578 fall in Quadrate I so these accessions were considered as best water tolerant for PCA2 (T_1). Selected accessions showed more variation for dry root weight followed by chlorophyll content, root length and leaf water content as these are shown by the vectors in graph. Accessions 17435, 17441, 17433, 17436, 17415, 24576, 24584, 24582, 24599 and 24601 fall in Quadrate III so these accessions are considered as water sensitive for PCA2 (T_1). Selected accessions were poor for all the studied water related traits.

Table 2. Mean squares from analysis of variance of soybeans under normal and water stress treatments.

SOV	DF	RL	SL	FSW	FRW	DSW	DRW	G%	SER	LA	CC	LWC
Replication (A)	2	8.3007	244.982	0.88120	0.01696	0.00247	4.74E×-05	2681.64	1766.90	8319.80	100.870	911.40
Treatment (B)	2	38.3463	390.948	0.23978	0.00008	0.00392	7.51E-04**	2276.22	2304.76	9006.48	91.426	1727.11**
Error A*B	4	11.5021	97.949	0.19151	0.00518	0.00128	2.230E-05	475.70	1038.02	4073.48	26.991	1020
Accessions (C)	79	63.0246**	530.499**	0.86648**	0.05421**	0.00765**	4.948E-04**	5010.39**	6250.56**	8062.40**	96.384**	157859**
B*C	158	37.1196**	176.055**	0.32867**	0.03057**	0.00280**	2.961E-04**	2294.83**	2413.82**	5932.62**	67.517**	245280**
Error A*B*C	474	3.7486	23.427	0.17129	0.00738	0.00041	2.666E-05	305.20	282.86	1463.56	14.955	188648

**= Significant at 0.01 probability level; *=Significant at 0.05 probability level

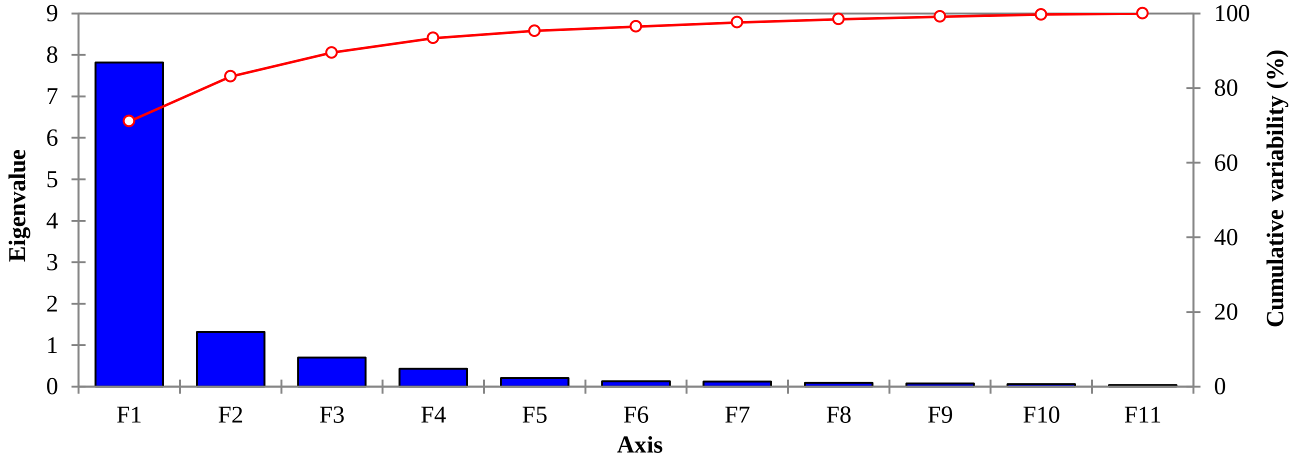
SOV= Sources of Variation, **DF=** Degrees of freedom, **RL=** Root Length, **SL=** Shoot Length, **FSW=** Fresh Shoot Weight, **FRW=** Fresh Root Weight**, DSW=** Dry Shoot Weight, **DRW=** Dry Root weight, **G%=** Germination Percentage, **SER=** Seedling Emergence Rate**, LA=** Leaf Area, **CC=** Chlorophyll Content, **LWC=** Leaf Water Content.

Table 3. Mean squares from analysis of variance of soybeans under temperature and photoperiod treatments.

SOV	DF	RL	SL	FSW	FRW	DSW	DRW	SER	G%	LT	Pl.C	EML	NoN
Replication (A)	2	1.410	12.15	0.03239	0.03210	0.00053	0.00012	20.9	109.67	3.8	0.00506	4.5	2.3292
Treatment (B	2	146.842**	1287.26**	0.58967**	0.06065	0.02110**	0.00185**	16320.6**	5692.20**	12380.9**	6.36600**	68078.7**	36.6885**
Error A*B	4	2.084	13.38	0.00567	0.01645	0.00086	0.00006	16.2	28.76	5.0	0.00129	2.3	1.3083
Accessions (C)	79	46.663**	307.74**	1.64590**	0.04730**	0.02800**	0.00070**	3138.8**	2811.29**	368.0**	0.15486**	583.8**	7.7856**
B*C	158	46.091**	222.57**	1.46374**	0.04145**	0.02678**	0.00055**	2573.8**	2652.51**	355.2**	0.11454**	384.7**	3.1689**
Error A*B*C	474	1.512	9.53	0.01232	0.00951	0.00331	0.00012	67.7	67.45	2.9	0.00277	10.6	0.3828

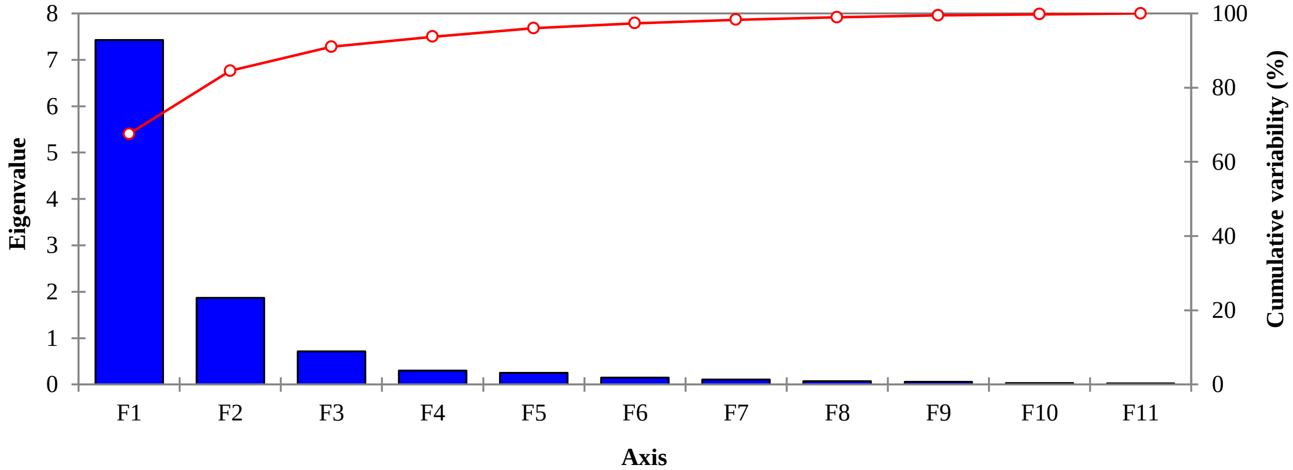
**= Significant at 0.01 probability level; *=Significant at 0.05 probability level

SOV= Sources of Variation, **DF=** Degrees of freedom, **RL=** Root Length, **SL=** Shoot Length, **FSW=** Fresh Shoot Weight, **FRW=** Fresh Root Weight**, DSW=** Dry Shoot Weight, **DRW=** Dry Root weight, **SER=** Seedling Emergence Rate, **G%=** Germination Percentage**, LT=** Leaf Temperature, **Pl.C=** Proline Content, **EML=** Electrolyte Membrane Leakage, **NoN=** Number of Nodes/Seedling



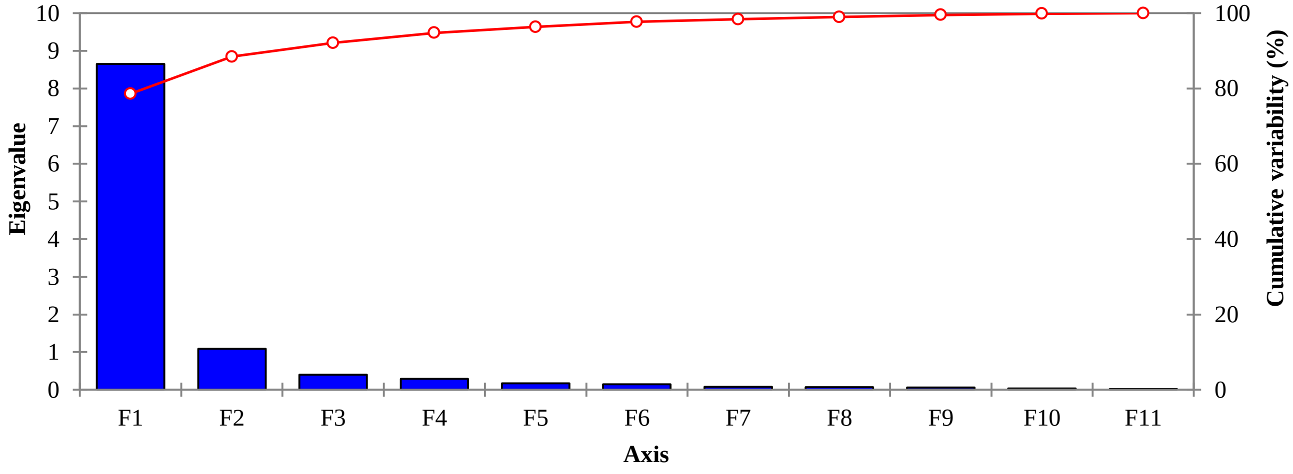
F1=Root length, **F2**= Shoot length, **F3**= Fresh shoot weight, **F4**= Fresh root weight, **F5**= Dry shoot weight, **F6**= Dry root weight, **F7**= Leaf area, **F8**= Chlorophyll content, **F9**= Leaf water content, **F10**= Seedling emergence rate, **F11=** Germination percentage

Fig. 1. Graphical presentation of Eigen values and variability % of water related traits of PCA1 (T_0).



F1=Root length, **F2**= Shoot length, **F3**= Fresh shoot weight, **F4**= Fresh root weight, **F5**= Dry shoot weight, **F6**= Dry root weight, **F7**= Leaf area, **F8**= Chlorophyll content, **F9**= Leaf water content, **F10**= Seedling emergence rate, **F11=** Germination percentage.

Fig. 2. Graphical presentation of Eigen values and variability % of water related traits of PCA2 (T_1).



F1=Root length, **F2**= Shoot length, **F3**= Fresh shoot weight, **F4**= Fresh root weight, **F5**= Dry shoot weight, **F6**= Dry root weight, **F7**= Leaf area, **F8**= Chlorophyll content, **F9**= Leaf water content, **F10**= Seedling emergence rate, **F11=** Germination percentage.

Fig. 3. Graphical presentation of Eigen values and variability% of water related traits of PCA3 (T_2).

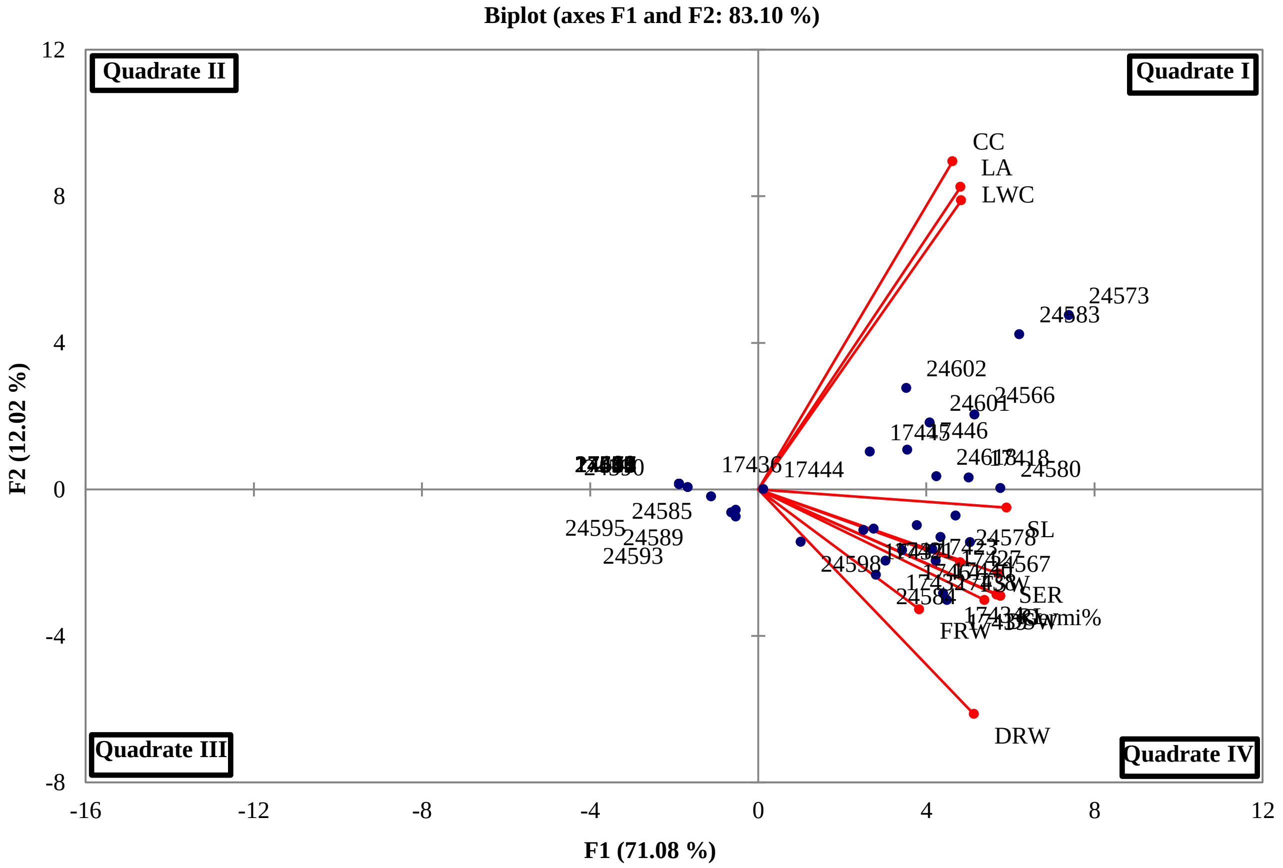


Fig. 4. PCA1 (T_0) of water related traits in soybeans.

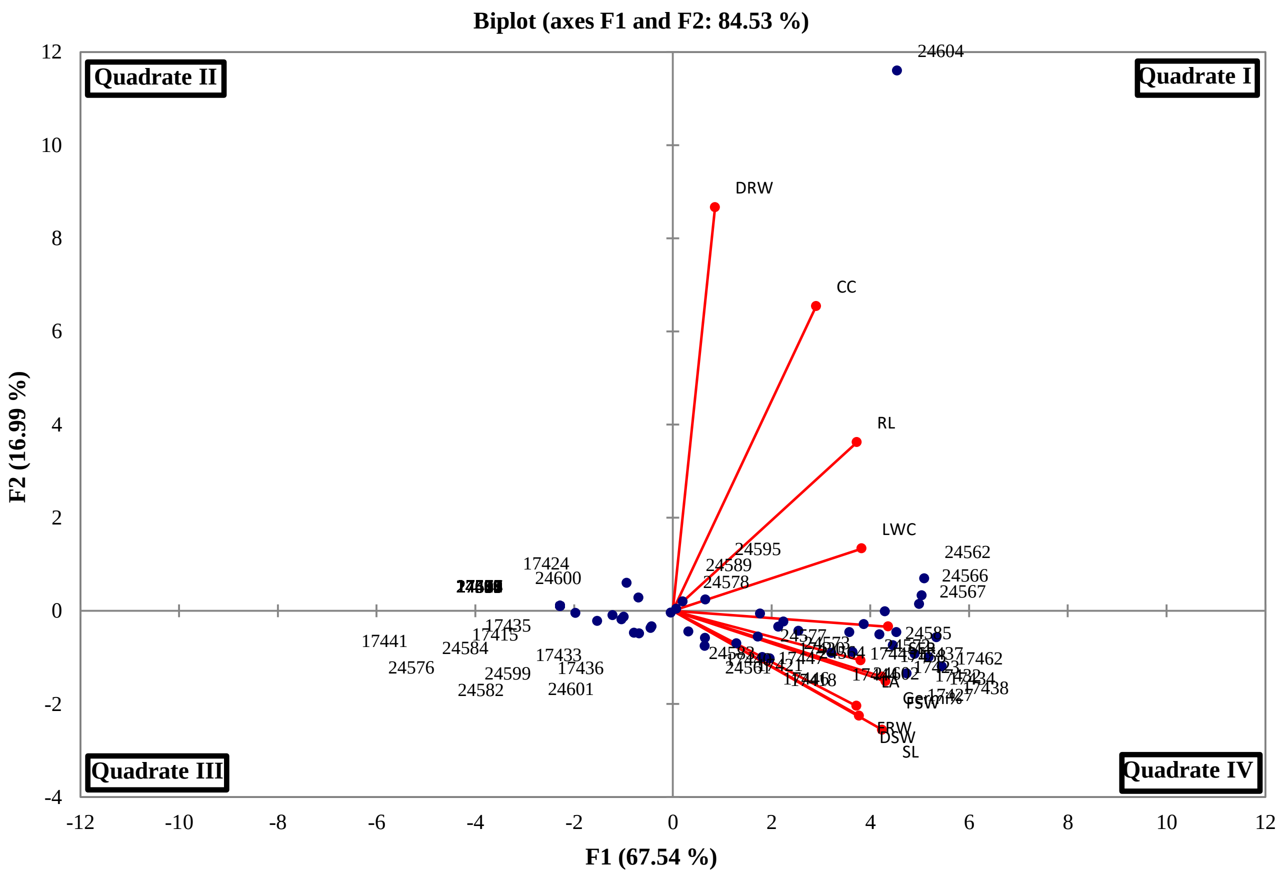


Fig. 5. PCA2 (T_1) of water related traits in soybeans.

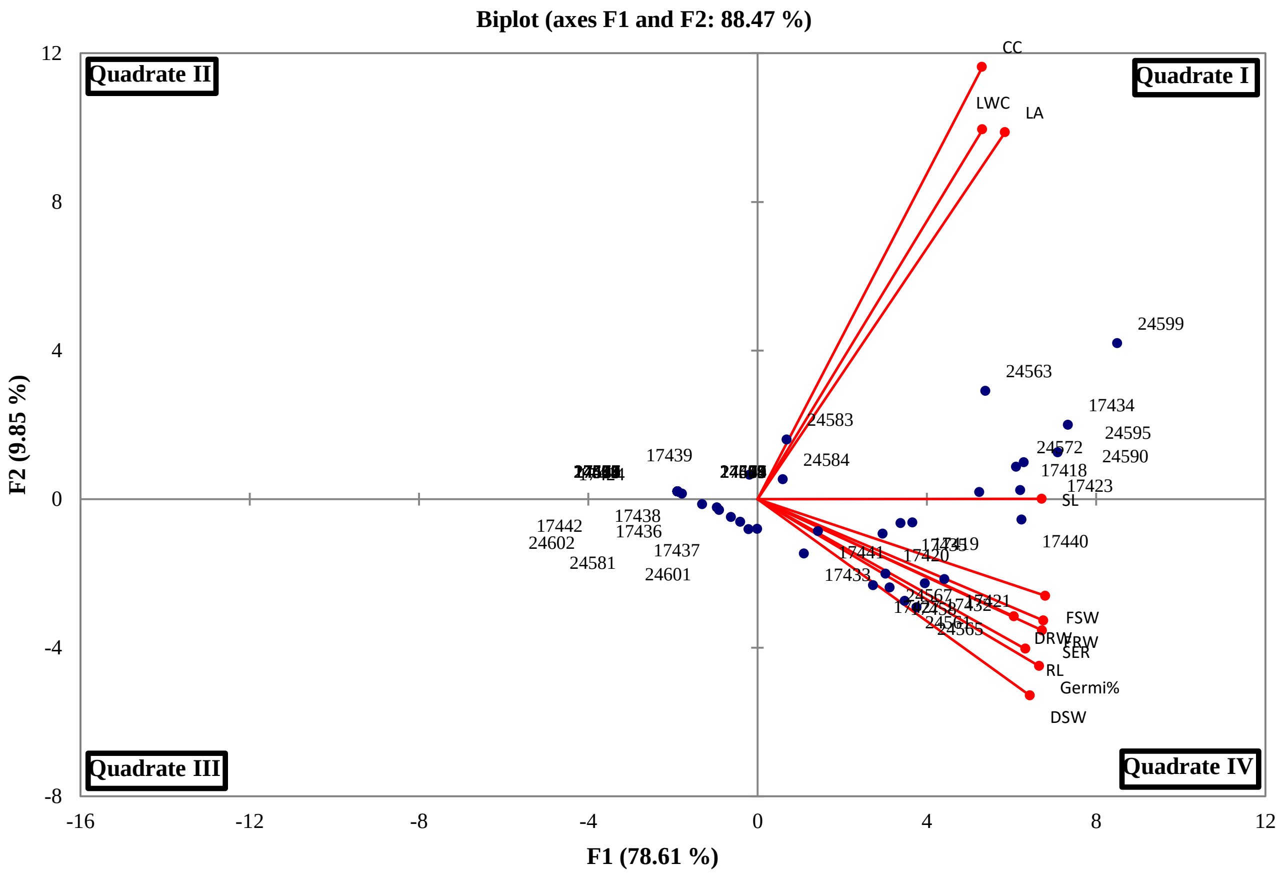


Fig. 6. PCA2 (T_1) of water related traits in soybeans.

Accessions 24599, 24563, 24583, 24584, 24590, 24595, 24572, 17434 and 17418 fall in Quadrate I so these accessions were considered as best water tolerant for PCA3 (T_2). Selected accessions showed more variation for chlorophyll content followed by leaf water content and leaf area as these are shown by the vectors in graph. Accessions 17436, 17438, 17437, 17442, 24602, 24601 and 24581 fall in Quadrate III so these accessions are considered as water sensitive for PCA3 (T_2). Selected accessions were poor for all the studied water related traits.

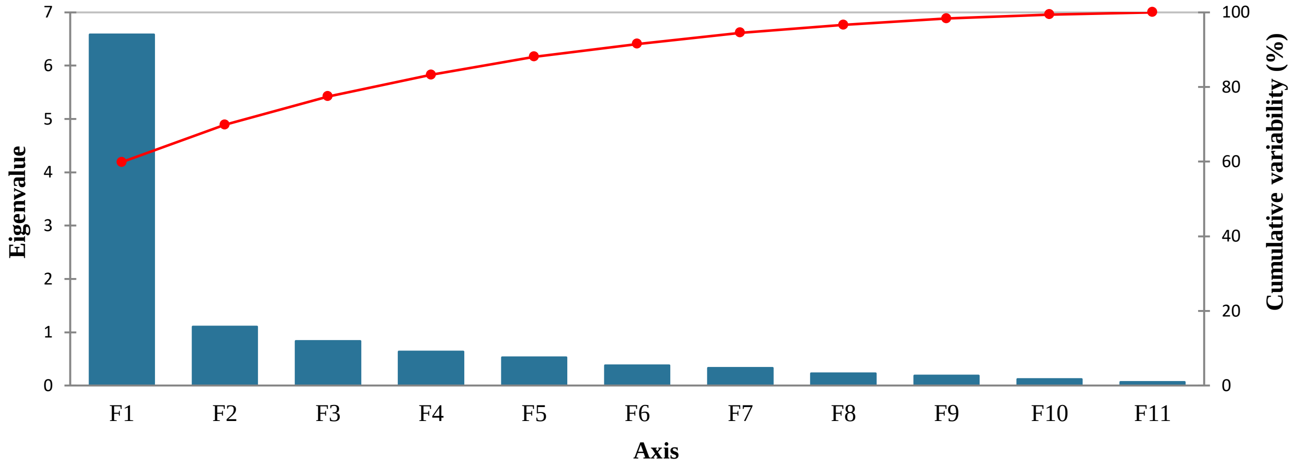
Principal component analysis of soybeans under normal and temperature stress treatments: Graphical presentation of Eigen values and variability% for temperature related traits of PCA1 (T_0= 30°C), PCA2 (T_1= 35°C) and PCA3 (T_2= 40°C) are presented in (Figs. 7, 8 and 9) respectively.

In present study, all the factors had Eigen value less than 1 except root length under all the treatments. Eigen value was more than 1 for shoot length in PCA1 (T_0) and PCA3 (T_2) while it was also more than 1 for fresh shoot weight in PCA3 (T_2). Contribution of root length and shoot length to total variation was 59.83% and 10.03% respectively for PCA1. While, contribution of root length, shoot length and fresh shoot weight to total variation was 38.94%, 60.55% and 75.01% respectively for PCA3 (T_2).

Graphs for PCA1 (T_0), PCA2 (T_1) and PCA3 (T_2) are presented in (Figs. 10, 11 and 12) respectively. Accessions 24567, 17415, 24569, 17421, 17446, 24601, 24583, 24602, 24577, 24574, 17419, 24566, 17461 and 24584 fall in Quadrate I so these accessions were considered as best temperature tolerant for PCA1 (T_0). Selected accessions were best for all the studied temperature related traits but showed more variation for fresh shoot weight, germination percentage and seedling emergence rate followed by leaf temperature as these are shown by the vectors in graph. No accessions fall in Quadrate III so any accession was not selected as temperature sensitive for PCA1 (T_0).

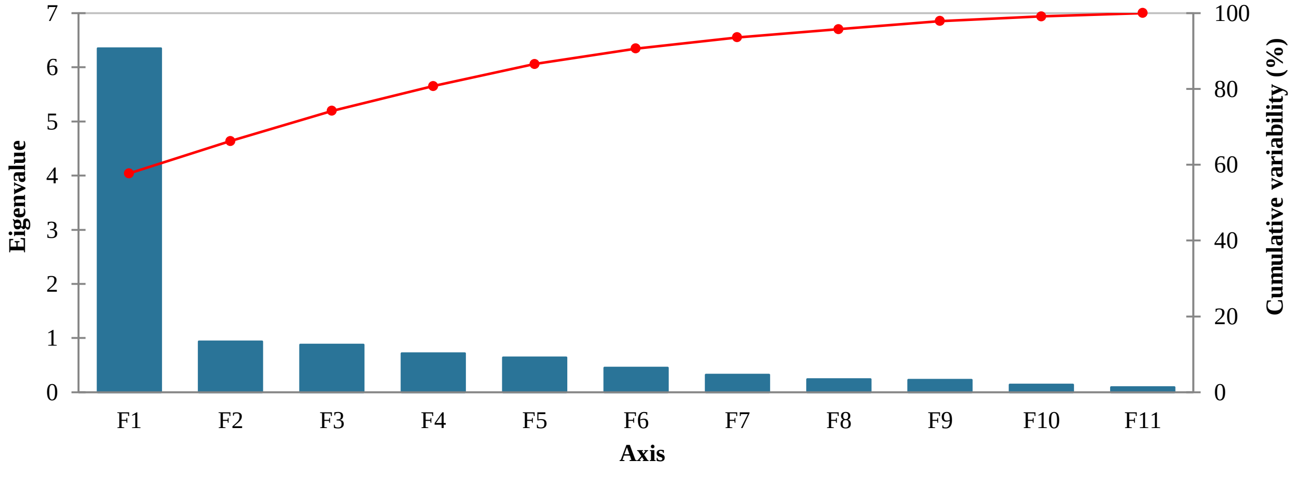
Accessions 17419, 17440, 17442, 17444, 24601, 24589, 17452, 24602, 24572, 24573 and 17438 fall in Quadrate I so these accessions were considered as best temperature tolerant for PCA2 (T_1). Selected accessions were best for all the studied temperature related traits but showed more variation for dry shoot weight and fresh root weight followed by leaf temperature as these are shown by the vectors in graph. Accessions 24576, 24581 and 24582 fall in Quadrate III so these accessions were considered as temperature sensitive for PCA2 (T_1).

Accessions 24566, 24567, 24572, 24577, 24590 and 24595 fall in Quadrate I so these accessions were considered as best temperature tolerant for PCA3 (T_2). Selected accessions were best for all the studied temperature related traits but showed more variation for root length followed by seedling emergence rate and fresh root weight as these are shown by the vectors in graph. Accessions 17449, 24603, 24606, 24604, 24579, 17442, 24589, 24597, 24587, 24580, 24562 and 17429 fall in Quadrate III so these accessions were considered as temperature sensitive for PCA3 (T_2).



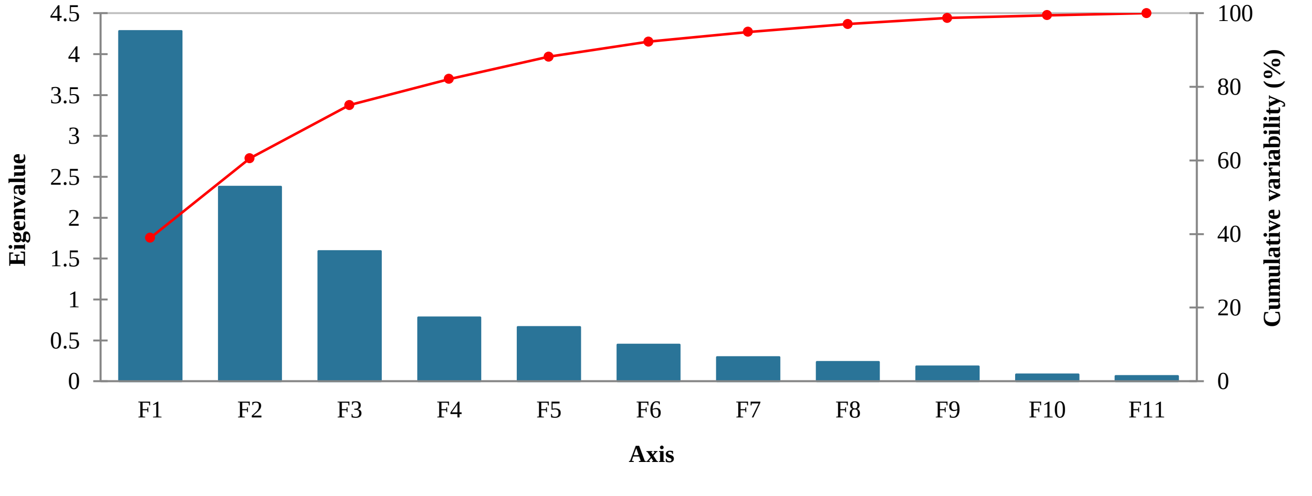
F1=Root length, **F2**= Shoot length, **F3**= Fresh shoot weight, **F4**= Fresh root weight, **F5**= Dry shoot weight, **F6**= Dry root weight, **F7**= Seedling Emergence Rate, **F8**= Germination %, **F9**= Leaf temperature, **F10**= Proline Content, **F11=** Electrolyte Membrane Leakage

Fig. 7. Graphical presentation of Eigen values and variability% of temperature related traits of PCA1 (T_0).



F1=Root length, **F2**= Shoot length, **F3**= Fresh shoot weight, **F4**= Fresh root weight, **F5**= Dry shoot weight, **F6**= Dry root weight, **F7**= Seedling Emergence Rate, **F8**= Germination %, **F9**= Leaf temperature, **F10**= Proline Content, **F11=** Electrolyte Membrane Leakage

Fig. 8. Graphical presentation of Eigen values and variability% of temperature related traits of PCA2 (T_1)



F1=Root length, **F2**= Shoot length, **F3**= Fresh shoot weight, **F4**= Fresh root weight, **F5**= Dry shoot weight, **F6**= Dry root weight, **F7**= Seedling Emergence Rate, **F8**= Germination %, **F9**= Leaf temperature, **F10**= Proline Content, **F11=** Electrolyte Membrane Leakage

Fig. 9. Graphical presentation of Eigen values and variability% of temperature related traits of PCA3 (T_2).

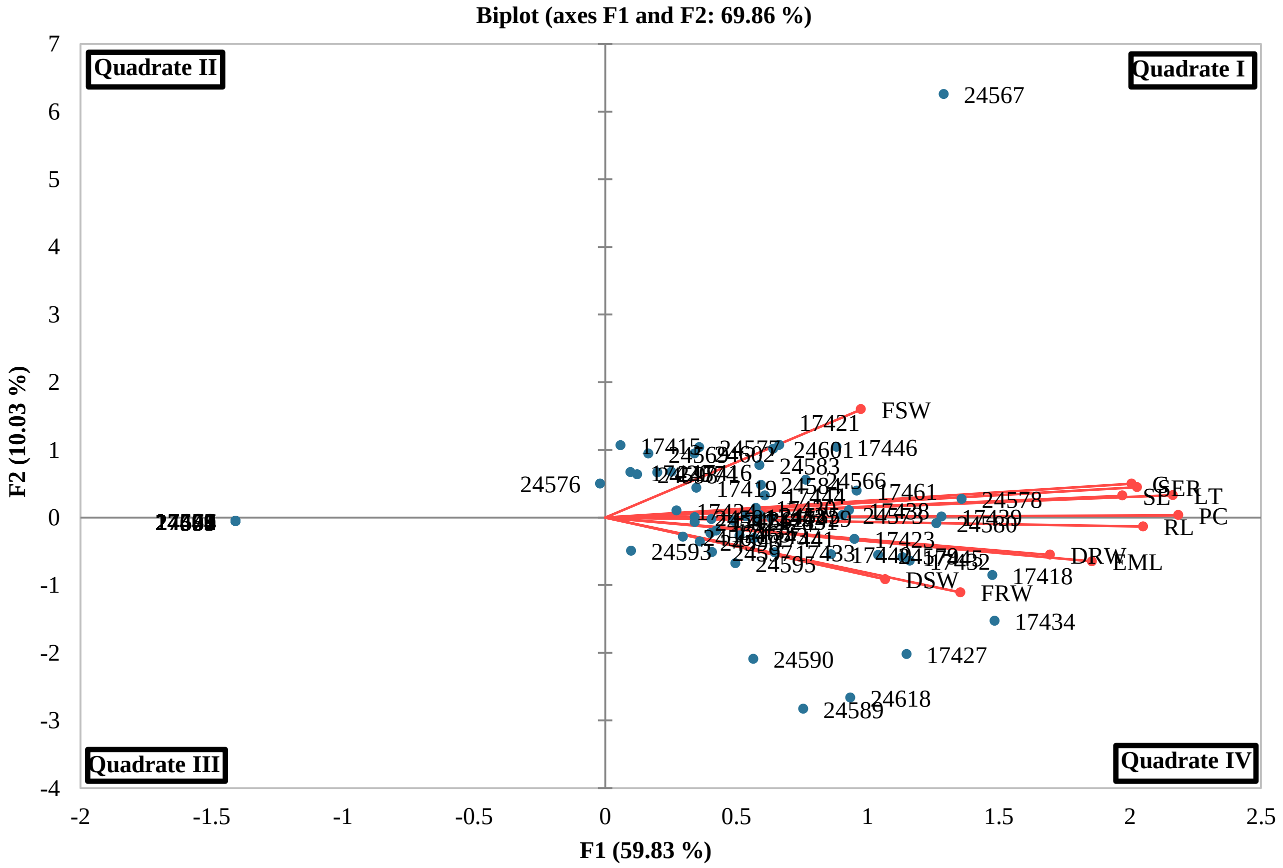


Fig. 10. PCA1 (T_0) of temperature related traits in soybean.

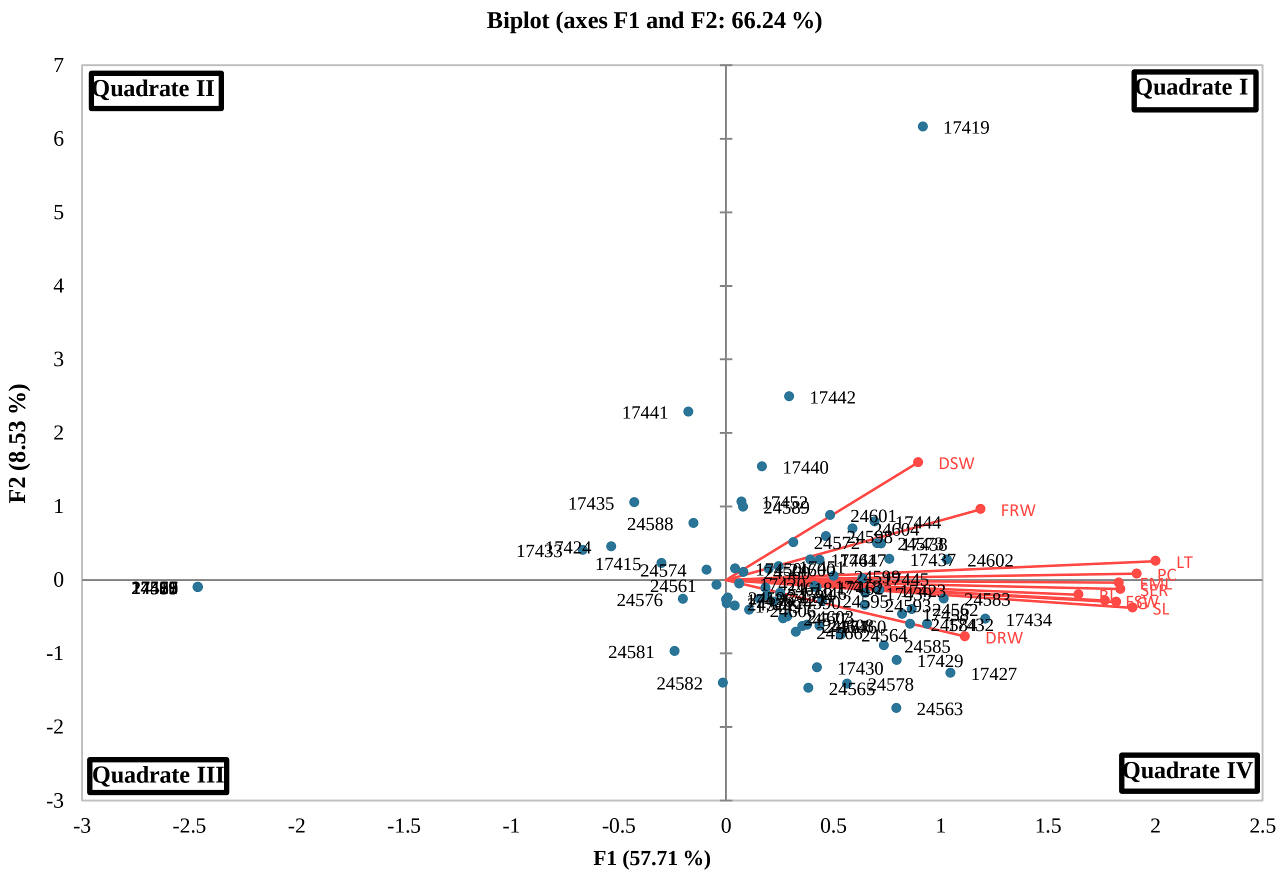


Fig. 11. PCA2 (T_1) of temperature related traits in soybeans.

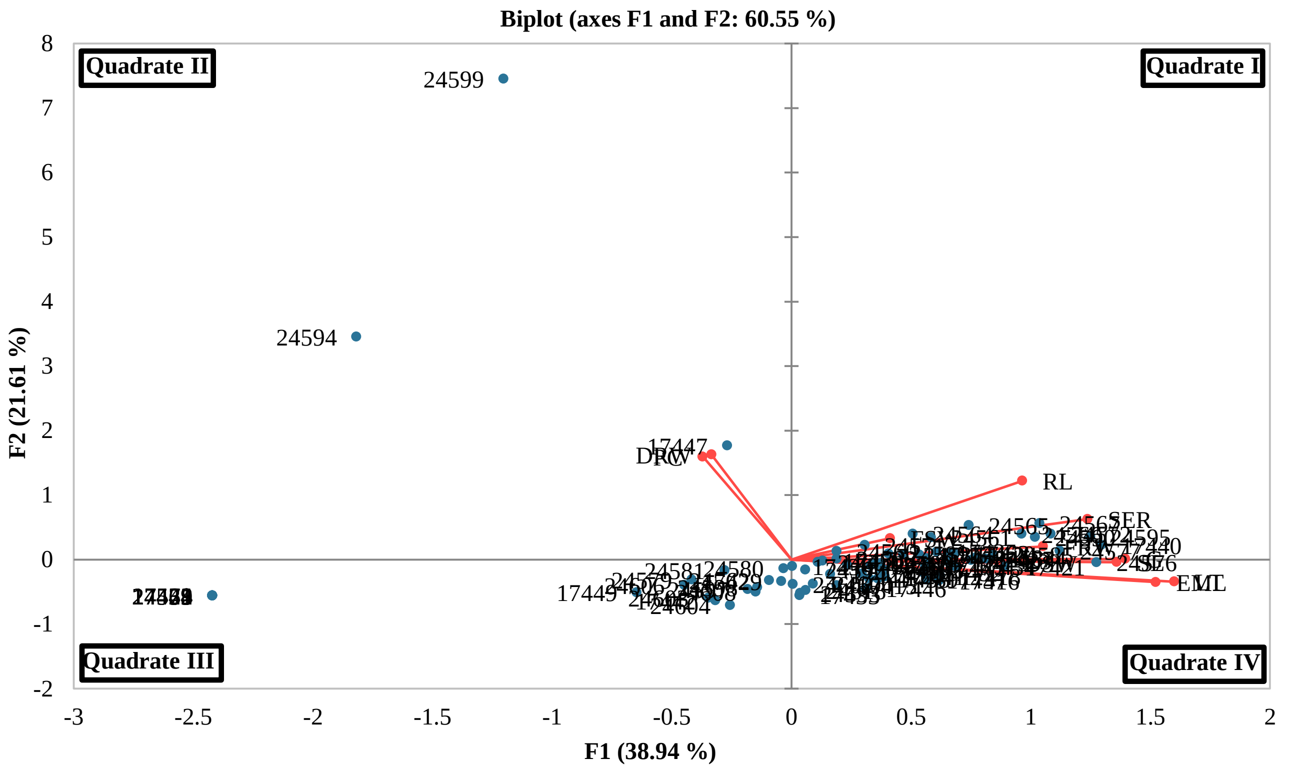


Fig. 12. PCA3 (T_2) of temperature related traits in soybeans.

Table 4. Mean values of seedling trait in soybean under photoperiod treatments.

Accession	No. of nodes/Seedling			Accession	No. of nodes/Seedling			Accession	No. of nodes/Seedling		
	T_0	T_1	T_2		T_0	T_1	T_2		T_0	T_1	T_2
17415	1.00	0.00	0.00	17447	0.00	1.50	0.00	24579	0.00	0.00	0.00
17416	0.00	0.00	0.00	17449	0.00	0.00	0.00	24580	1.00	1.00	0.00
17418	2.33	3.00	3.17	17450	1.00	0.00	0.00	24581	0.00	0.00	2.17
17419	0.00	0.00	3.33	17451	0.50	0.50	0.00	24582	0.00	0.00	0.00
17420	0.83	2.50	4.17	17452	0.00	0.00	0.00	24583	1.33	1.33	3.50
17421	1.67	2.33	2.67	17458	0.33	0.33	3.33	24584	0.67	0.67	3.17
17423	3.00	3.00	3.00	17459	0.67	0.67	0.00	24585	0.67	0.67	1.67
17424	0.00	0.67	3.00	17460	0.00	0.00	0.00	24587	1.00	1.00	0.00
17427	1.33	1.67	3.00	17461	1.00	1.00	0.00	24588	0.33	0.33	0.00
17428	0.00	0.00	0.00	17462	0.00	0.00	0.00	24589	0.83	0.83	0.00
17429	0.67	0.00	0.00	17463	0.67	0.67	0.00	24590	0.83	0.83	4.00
17430	0.00	0.00	0.00	24560	1.00	1.00	0.00	24593	0.00	0.00	0.00
17431	0.00	0.00	0.00	24561	0.00	0.00	4.17	24594	0.00	0.00	0.00
17432	1.00	2.33	3.67	24562	0.33	0.33	0.00	24595	0.00	0.00	3.83
17433	0.00	0.33	1.67	24563	0.00	0.00	3.00	24596	0.67	0.67	0.00
17434	1.00	3.00	3.00	24564	0.67	0.67	0.00	24597	0.00	0.00	0.00
17435	0.00	0.00	4.00	24565	0.00	0.00	3.00	24598	1.33	1.33	0.00
17436	0.33	1.17	3.33	24566	2.00	2.00	0.00	24599	0.00	0.00	3.83
17437	0.67	2.00	2.67	24567	2.33	2.33	3.17	24600	0.00	0.00	2.33
17438	2.00	3.00	2.00	24569	0.00	0.00	0.00	24601	2.00	2.00	3.17
17439	2.00	0.00	2.50	24571	0.00	0.00	0.00	24602	1.83	1.83	1.50
17440	0.33	1.33	3.83	24572	0.00	0.00	3.00	24603	0.00	0.00	0.00
17441	0.00	2.50	2.50	24573	2.33	2.33	2.33	24604	0.00	0.00	1.67
17442	0.67	0.67	1.50	24574	0.00	0.00	0.00	24606	0.67	0.67	0.00
17444	0.00	2.67	0.00	24576	0.00	0.00	0.00	24608	0.00	0.00	0.00
17445	1.33	3.00	3.67	24577	0.00	0.00	0.00	24618	1.33	1.33	0.00
17446	1.67	2.33	0.00	24578	2.00	2.00	2.33				

Mean values of soybeans under normal and photoperiod stress treatments: Mean values of soybeans for number of nodes/seedling under (T_0= 10 hours, T_1= 11 hours and T_2= 13 hours) are presented in (Table 4). Increasing trend in number of nodes/seedling was observed with increasing photoperiod. Number of nodes/seedling ranged from 0.0-3.00 (T_0), 0.0-3.00 (T_1) and 0.0-3.83 (T_2). Accession 17452, 17418, 17434, 17429 and 24569 had highest mean number of nodes/seedling under T_0 that is 3.00, 2.33, 2.33, 2.33 and 2.00 respectively. Accession 24576, 24562, 17461, 17444 17428 had highest mean number of nodes/seedling at stress level T_1 that is 3.00 for each accessions. Accession 24561, 17420, 24590, 17435 and 24599 had highest mean number of nodes/seedling under T_2 that is 4.16, 4.16, 4.00, 4.00 and 3.83 respectively.

Selection of soybeans: On the basis of Principal component analysis (temperature and water) and mean values (photoperiod) five best common accessions (17434, 17418, 17444, 24566 and 24567) were selected as Principal component is not suitable for single trait experiment. Hence, principal component analysis and means values can be further used in selection of potential parents for adaptation.

Discussion

Water stress generally reduces plant productivity and growth by reducing different water related parameters i.e. chlorophyll contents, fresh and dry root and shoot weight, leaf area, leaf water content, and shoot length and water use efficiency (Ueda *et al*., 2003; Ohashi *et al*., 2006; Munns, 2002; James *et al*., 2008; Farooq *et al*., 2009). Analysis of variance of present study showed that significant differences are present among soybeans under normal and water stress treatments for studied traits. Sakazono *et al*., 2014 reported significant differences for dry root and shoot weight among lines and water treatments and their interaction in soybean. According to Nakagawa (1999), cultivars with a higher dry mass are considered to be more vigorous, transferring a greater amount of dry matter from the reserve tissues to the embryonic axis during seed germination. Chlorophyll is important in photosynthesis with function of light energy transformation and light absorbance (Xu *et al*., 2000; Glaszmann *et al*., 1990; Wu *et al*., 1997). It significantly decreases with increase in stress (Fuzy *el al*., 2019). Chlorophyll content of leaves of plant has been a good stress indicator (Chaves *et al*., 2009; Ueda *et al*., 2003; Mehta *et al*., 2010; Li *et al*., 2006). Rosadi *et al*., 2005 and Baghbani *et al*., 2017 reported decrease in root length with increased water stress. Sakazono *et al*., 2014 and Yan *et al*., 2020 reported significant differences for root length among lines, water treatments and their interaction in soybean. Santorum *et al*., 2013 and Camila *et al*., 2017 observed significant differences among soybean accessions for seed germination, emergence rate, shoot length, fresh shoot and root weight and also increasing trend in germination percentage among soybean accessions. Literature studies reported significant differences in leaf area of soybean under different water treatments (Zhang *et al*., 2016; Yan *et al*., 2020) and decrease in leaf area with increase in water stress (Ohashi *et al*., 2006; Mejia *et al*., 2000). Leaf water content significantly changes under water stress condition that shows suitability of leaf water content as symptom characteristic (Fuzy *el al*., 2019; Zhang *et al*., 2016). Literature studies reported that water content of soil during growth of soybean should not exceed 85 percent or be less than 50 percent (Doorenbos & Kassam, 1986).

Analysis of variance of present study showed that significant differences are present among soybeans under normal and temperature stress treatments for studied traits. Literature studies revealed that significant differences were present among soybean cultivars for root growth development, plant components dry weight, physiological parameters and shoot growth and development among low and high temperature treatments (Wijewardana *et al*., 2015; Khan *et al*., 2016; Reddy *el al*., 2017; Singh *et al*., 2018). Lamichhane *et al*., (2019) reported that optimum temperature for soybean germination was 30°C and temperature stress significantly affected germination and seedling emergence of soybean. When the plants are under temperature stress, cellular membrane structure is damaged. The degree of injury of cell membrane induced by temperature stress can be due to intracellular electrolyte membrane leakage rate. Relative value of conductance is one of the effective indicators to evaluate plant response to temperature stress (Steponkus, 1984; Steponkus, 1990). Liu *et al*., (2013) found that with increased temperature stress electrolyte membrane leakage increased more significantly. Szczerba *et al*., (2021) reported that temperature stress significantly affected seed germination and electrolyte membrane leakage of all studied soybean cultivars. Proline is an organic osmolyte and it is widely distributed in plants as a protection material. It plays a vital role in stabilizing structures and maintaining osmotic balance (Verbruggen & Hermans, 2008; Igarashi *et al*., 1997). Liu *et al*., (2013) and Liu *et al*., (2009) found that there was accumulation of free proline when plants are exposed to temperature stress.

Analysis of variance of number of nodes/seedling showed that significant differences are present among soybeans under normal and photoperiod stress treatments. Also, number of nodes increased with increase in photoperiod. Nico *et al*., (2016) reported that under long photoperiods, soybean plants had more flowering nodes. Soybean is usually referred to as a short-day plant and a dark period of 10.5 hours for at least two consecutive photoperiodic cycles is enough to trigger flower induction at floral nodes (Parker *et al*., 1946).

On the basis of principal component analysis (water and temperature) and mean values (photoperiod) five best accessions were selected as principal component analysis is not useful for single trait experiments. Mean values of these traits are considered suitable for the selection of the accessions under different climatic conditions (Darvishzdaeh *et al*., 2010) but there is need to use a method to improve the efficiency of selection, a major challenge in plant breeding programs. For the management of multipara-metric data and selection of accessions under given environment principal component analysis can be guidance among trails and a useful tool (Sutka *et al*., 2011; Chen *et al*., 2014; Maruyama *et al*., 2014; Dresler *et al*., 2014). Alsajri *et al*., 2019 conducted an experiment in a controlled-environment facility to quantify 64 soybean cultivars at optimum and high temperature during the seedling growth stage. Several shoot, root and physiological parameters were assessed at 20 days after sowing `and found significant differences in the measured root, shoot, and physiological parameters at both low and high temperatures. Other studies also reported use of principal component analysis for selections of soybeans (Iqbal *et al*., 2008; Singh *et al*., 2018).

Conclusion

Genetic variability among soybeans can be further used for adaptability and yield improvement programme in soybean. On the basis of principal component analysis (water and temperature) and mean values (photoperiod) five best common soybean accessions 17434, 17418, 17444, 24566 and 24567 were selected that can be used as potential parents for the development of breeding material and may be further evaluated under different climatic conditions to study their worth for adaptation.

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