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Effective selection criteria for screening drought tolerant landraces of bread wheat (*Triticum aestivum* L.)

Ezatollah Farshadfar[1*], Zahra Moradi[2], Parvin Elyasi[1], Bita Jamshidi[1], Roghaye Chaghakabodi[1]

[1]College of Agriculture, Razi University, Kermanshah, Iran
[2]Department of Plant Breeding, Islamic Azad University, Kermanshah Branch, Kermanshah, Iran

ABSTRACT

In order to evaluate the ability of several selection criteria to identify drought tolerant landraces of bread wheat 20 landraces were evaluated in a randomized complete block design with three replications under irrigated and rainfed conditions. Fourteen drought tolerance indices including stress tolerance index (STI), geometric mean productivity (GMP), mean productivity index (MP), stress susceptibility index (SSI), tolerance index (TOL), yield index (YI), yield stability index (YSI), drought response index (DRI), drought resistance index (DI), modified stress tolerance index (MSTI), relative drought index (RDI), abiotic tolerance index (ATI), stress susceptibility percentage index (SSPI) and stress non-stress production index (SNPI) were calculated and adjusted based on grain yield under drought (Ys) and irrigated conditions (Yp). Significant positive correlation was found between grain yield in the stress condition (Ys) with criteria STI, GMP, MP, YI, YSI, DI, K_1STI, K_2STI, RDI, SNPI, SSI and DRI indicating that these indices discriminate drought tolerant genotypes in the same manner. Principal component analysis (PCA), exhibited that first and second PCA accounted for 99.02% of the variation. Screening drought tolerant genotypes using mean rank, standard deviation of ranks and biplot analysis, discriminated genotypes (15), (3) and (6) as the most drought tolerant. Therefore they are recommended to be used as parents for genetic analysis, gene mapping and improvement of drought tolerance in common wheat.

Key words: Bread wheat, drought tolerance indices, screening methods.

INTRODUCTION

Global warming and concomitant increase in drought effected areas limit plant production in the world. Wheat production is also restricted by drought exposed areas and this loss led to considerable economic and social problems because of its great importance on human nutrition [1]. Selecting wheat genotypes based on their yield performance under drought conditions is a common approach, therefore some drought stress indices or selection criteria have been suggested by different researches [2, 3]. The impact of water shortage (availability at farm gate) and lower rainfall during the sowing period seems to be the main reason for lesser acreage under wheat crop and reduction in wheat production. Therefore, breeding for drought tolerant wheat is an important task and objective in the present scenario [4].

Breeding for drought resistance is complicated by the lack of fast, reproducible screening techniques and the inability to routinely create defined and repeatable water stress conditions when a large amount of genotypes can be evaluated efficiently [5]. Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in grain yield has been much higher in favourable environments [6]. Thus, drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes [7].

Stress tolerance index (TOL) and mean productivity (MP) were defined as the difference in yield and the average yield between stress and non-stress environments, respectively [8]. Other yield based index is geometric mean productivity (GMP) that is often used by breeders interested in relative performance since drought stress can vary in severity in the field environment over years [5]. Another selection criterion for a high yielding cultivar under drought conditions is stress susceptibility index (SSI) proposed by Fischer and Maurer [9]. Lan [10] and Fernandez [11] defined new indices of drought resistance index (DI) and stress tolerance index (STI), which were commonly accepted to identify genotypes producing high yield under both stress and nonstress conditions.

Fischer et al. [12] introduced another index as relative drought index (RDI). Bidinger et al. [13] suggested drought response index (DRI) with its positive values indicating stress tolerance. Other yield based estimates of drought resistance are yield index (YI) [14] and yield stability index (YSI) [15].

To improve the efficiency of STI a modified stress tolerance index (MSTI) was introduced by Farshadfar and Sutka [16] as ki STI, where ki is a correction coefficient which corrects the STI as a weight. Therefore, k_1 STI and k_2 STI are the optimal selection indices for stress and non-stress conditions, respectively.

Fernandez [11], divided the manifestation of plants into the four groups of (I) – genotypes that express uniform superiority in non-irrigated and irrigated conditions (group A), (II)- genotypes which perform favorably only in nonstress conditions (group B), (III) - genotypes which yield relatively higher only in stress conditions (group C) and (IV) - genotypes which perform poorly in non-irrigated and irrigated conditions (group D). Therefore, as Fernandez stated, the best index for stress tolerance selection is one that can be able to separate group A from others. We believe that the best index for relative tolerance or relative resistance depends on the selection aims (only selection for stability without attention to high yield or selection for commercial aims with attention to stable and high yield) and the conditions of selection (the selection aim is for non-irrigated or irrigated conditions).

Moosavi et al. [17] recommended testing of new indices (ATI) that can select group C with more emphasis on YP than SSI and TOL for identification of relative tolerant genotypes (stable yield in non-irrigated and irrigated conditions), SSPI for better understanding of yield changes and identification of relative tolerant genotypes (stable yield in non-irrigated and irrigated conditions) and SNPI for selection of relatively resistant genotypes with relatively stable and high yield in non-irrigated and irrigated conditions.

The objectives of the present investigation were to screen bread wheat landraces for drought tolerance with high yield potential and stability under water stress conditions.

MATERIALS AND METHODS

Twenty landraces of bread wheat (*Triticum aestivum* L.) listed in Table 1 were provided from Seed and Plant Improvement Institute of Karaj, Iran. They were assessed in a randomized complete block design with three replications under two irrigated and rainfed conditions during 2010-2011 growing season in the experimental field of the College of Agriculture, Razi University, Kermanshah, Iran (47° 9′ N, 34° 21′ E and 1319 m above sea level). Mean precipitation in 2010–2011 was 509.50 mm. The soil of experimental field was clay loam with pH7.1. Sowing was done by hand in plots with four rows 2 m in length and 20 cm apart. The seeding rate was 400 seeds per m^2 for all plots. At the rainfed experiment, water stress was imposed after anthesis. Non-stressed plots were irrigated three times after anthesis, while stressed plots received no water. At harvest time, yield potential (Yp) and stress yield (Ys) were measured from 2 rows 1 m in length. Drought resistance indices were calculated using the following relationships:

1) **Stress susceptibility index** = $SSI = \frac{1-(Y_S/Y_P)}{1-(\bar{Y}_S/\bar{Y}_P)}$ [9].

2) **Relative drought index** = RDI= $(Ys/Y_p)/(\bar{Y}_S/\bar{Y}_P)$ [12].

3) **Tolerance** = TOL = $Y_P - Y_S$ [8].

4) **Mean productivity** = $MP = \frac{Y_S + Y_P}{2}$ [8].

5) **Stress tolerance index** = $STI = \frac{Y_S \times Y_P}{\bar{Y}_P^2}$ [11].

6) **Geometric mean productivity** = $GMP = \sqrt{(Y_S \times Y_P}$ [11].

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7) **Yield index** = $YI = \frac{Y_S}{\overline{Y}_S}$ [14].

8) **Yield stability index** = $YSI = \frac{Y_S}{Y_P}$ [15].

9) **Drought response index** = DRI= $(Y_A - Y_{ES}) / (S_{ES})$ [13].

10) **Drought resistance index** (DI) = Ys × (Ys/Yp)/ $\overline{Y}_S$ [10].

11) **Modified stress tolerance index** = MSTI = ki STI , $k_1 = Y_p^2 / \overline{Y}_P^{\,2}$ $k_2 = Y_s^2 / \overline{Y}_S^{\,2}$ [16] where ki is the correction coefficient.

12) **Abiotic tolerance index** = ATI =$[(Yp-Ys) / (\overline{Y}_P / \overline{Y}_S)] \times [\sqrt{Yp \times Ys}]$ [17].

13) **Stress susceptibility percentage index** = SSPI=$[Yp-Ys / 2(\overline{Y}_P)] \times 100$ [17].

14) **Stress non-stress production index** =

= SNPI = $\sqrt[3]{Yp + Ys) / (Yp - Ys)}\ ] \times [\ \sqrt[3]{3 \times Ys \times Ys}\ ]$ [17].

In the above formulas, Y_S, Y_P, $\overline{Y}_S$ and $\overline{Y}_P$ represent yield under stress, yield under non-stress for each genotype, yield mean in stress and nonstress conditions for all genotypes, respectively. Y_A, Y_{ES} and S_{ES} are representative of yield estimate by regression in stress condition, real yield in stress condition and the standard error of estimated grain yield of all genotypes, respectively.

For screening drought tolerant genotypes a rank sum (RS) was calculated by the following relationship:

Rank sum (RS) = Rank mean ($\overline{R}$) + Standard deviation of rank (SDR) and SDR= $(S^2_i)^{0.5}$.

Statistical analysis

Correlation analysis and principal component analysis (PCA), based on the rank correlation matrix and biplot analysis were performed by SPSS ver. 16, STATISTICA ver. 8 and Minitab ver.16.

RESULTS AND DISCUSSION

Data concerning yield (Yp and Ys) and indices are given in Table 2. The estimates of stress tolerance attributes (Table 2) indicated that the identification of drought-tolerant genotypes based on a single criterion was contradictory. For example, according to STI, genotypes 18, 15 and 8 were the most drought tolerant, whereas genotypes 10, 11 and 4 the least relative tolerant genotypes. With regard to GMP genotypes 15, 18 and 8 were the most relative tolerance and according to MP genotypes 18, 15 and 8 showed the most relative tolerance. Mevlüt and Sait [18] indicated that the genotypes with high STI usually have high difference in yield in two different conditions. They reported in general, similar ranks for the genotypes were observed by GMP and MP parameters as well as STI, which suggests that these three parameters are equal for selecting genotypes.

According to TOL, the desirable drought-tolerant genotypes were 19, 7 and 5. As to SSI, the desirable drought-tolerant genotypes were 10, 11 and 4. According to YI and YSI genotypes 15 and 18 were the most and 10 and 11 the least relative tolerant genotypes (Table 2). According to DI and DRI indices selected the genotypes 15 and 3 as the most relatively tolerant genotypes while for RDI the genotypes 3, 17 and 1 were the most relative tolerant. According to K_1STI the genotypes 18, 8 and 19 and according to K_2STI the genotypes 15, 18 and 3 were the most relative tolerant. ATI and SSPI discriminated genotypes 17, 3,1 and 19 as the best and 7 as the worst relatively tolerant genotypes, while for SNPI the genotype 3, 15, 17, 1, 18 exhibited the best and landraces 10, 11, 14 displayed the worst relatively resistant genotypes respectively.

Correlation analysis

Correlation analysis between grain yield and drought tolerance indices (Table 3) can be a good criteria for screening the best genotypes and indices used. Yield in stress (Ys) condition was significantly and positively correlated with STI, GMP, MP, YI, YSI, DI, K_1STI, K_2STI, RDI, SNPI, SSI and DRI (Table 3) therefore these indices are identified as drought tolerance criteria and discriminate drought tolerant genotypes in the same manner. Mollasadeghi [19] showed that correlation between MP, Yp and Ys was positive. Akçura et al. [20] reported that YI, YSI, STI, GMP, MP and HM were significantly and positively correlated with stress yield and these indices showed that cultivars may be ranked only on the basis of their yield under stress and so does not discriminate genotypes of group A. It was interesting to note positive correlation between SSI and Yp indicating that stress susceptibility was positively correlated with non-stressed yield [12, 21]. This suggested that some characteristics that contribute to yield potential may act to increase susceptibility to stress and that selection for both SSI and Yp may counteract each other. However, Ehdaie and Shakiba [22] in wheat found that there was no correlation between stress susceptibility and yield under optimum environments.

Clarke et al. [23] showed that yield-based SSI index did not differentiate between potentially drought resistant genotypes and those that possessed low overall yield potential. The geometric mean (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments and over years [11]. The STI, GMP and MP were used for screening drought tolerant high yielding genotypes in the both conditions [11, 24].

Three dimensional plot

A three-dimensional plot between Yp, Ys and STI (Fig. 1) was used to distinguish the group A genotypes from the other three groups (B, C and D) [11, 25]. In this case the most desirable genotypes for irrigated and rainfed conditions were 15, 3 and 18.

Fernandez [11] reported that MP also was able to differentiate genotypes belong to A-group (including genotypes with high yield performance in both conditions, from the others (B, C or D groups). MP is related to yield under drought stress if it is not too severe and the difference between Yp and Ys is not too large. In these cases, genotypes with a high MP would belong to A-group [26]. Golmaghani et al. [27] reported that the potential of indices MP, GMP, STI and YI to identify genotypes with high yield is higher than TOL and SSI. Khalil Zadeh and Karbalayi Khiavi [28], and Farshadfar et al. [25] believe that the most suitable indices for selection of drought tolerant cultivars, is an indicator which has a relatively high correlation with grain yield in both stress and non-stress conditions. Therefore the correlation between indices of stress tolerance and yield in both conditions, identify the most suitable indicators for screening drought tolerant genotypes.

Screening drought tolerant genotypes and indices

1-Principal component and biplot analysis for screening drought tolerance indicators

The relationships among different indices are graphically displayed in a biplot of PCA_1 and PCA_2 (Fig. 2). The PCA_1 and PCA_2 axes which justify 99.02% of total variation, mainly distinguish the indices in different groups. In Principal component analysis (PCA), the PCs axes divided the indices into four groups. Group 1 (G1) included only the parameter RDI. In group 2 (G2), the parameters DRI, DI, SNPI, Ys, K_2STI, YI, YSI, GMP, STI, MP and SSI are strongly correlated with yield under rainfed condition indicating that these criteria are suitable for identification of drought tolerat genotypes in the stress condition (group C of Fernandez). Indices K_1STI and Yp we refer to group 3 (G3), and ATI, SSPI and TOL were separated as group 4 (G4). In general indices in the same group distinguish drought tolerant genotypes in the same manner. This procedure was also employed in durum and bread wheat [29, 30] for screening selection criteria of different climate and water regime conditions.

Several studies conducted in Iran measuring drought response of improved wheat varieties [31], pure lines derived from winter wheat landraces [32], and spring wheat landraces [33] revealed that indices such as SSI and TOL were not efficient to be used in selecting genotypes with high yield capacity in either stressed or non-stressed environments. Saba et al. [34] reported that STI and SP were identified as efficient indices. SSI and TOL indices only assess the plasticities of the genotypes under study, whereas a variety may rank first in both environments but still have higher SSI and TOL than other varieties. Based on their studies, it seemed that SSI and TOL were not useful indices to select for drought tolerant genotypes in plant breeding programs, because, SSI exhibited negligible heritability and TOL was less heritable than other indices usually not identifying genotypes with both high yield and drought tolerance characteristics. On the other hand indiex like STI was moderately heritable and is usually able to select high yielding genotypes in both environments. Golabadi et al. [35] reported that selection for TOL will be worthwhile only when the target environment is no-drought stressed. Hohls [36] thought that MP should increase yield in both environments unless the genetic variance under stress is more than double that under non-stress, and the genetic correlation between yields in contrasting environments is highly negative.

Bouslama and Schapaugh [15] stated that cultivars with a high YSI were expected to have high yield under both stress and non-stress conditions. However, Sio-Se Mardeh et al. [37] found that cultivars with the highest YSI exhibited the least yield under non-stressed conditions and the highest yield under stressed conditions.

The two indices namely ATI and SSPI revealed a relative tolerance of a cultivar to drought stress. The nature of ATI and SSPI are such that they rely on crop survival mechanisms in stress conditions although these genotypes can have either high or low yields in two conditions so, they have not exhibited a significant correlation with high YS but have shown a significant correlation with YP. The yield stability is more importance than high yield in rainfed and irrigated conditions for these indices.

Although SNPI and STI are very similar and highly correlated, but in addition to high yield in stress and non-stress conditions, stable yield and high YS are more emphasized in SNPI than in STI, and these characteristics, make SNPI a better index than STI for identifying genotypes with stable and high yield in both stress and non-stress conditions [17]. Therefore, this index is an indicator of the relative stress resistance (because this index select tolerant genotypes with high yield in stress and non-stress conditions) while, indices ATI and SSPI show relative stress tolerance.

2- Biplot diagram

Selection based on combination of indices may provide a more useful criterion for improving drought resistance of wheat but study of correlation coefficients are useful in finding out the degree of overall linear association between any two attributes. Thus a better approach than correlation analysis and principal component is needed to identify the superior genotypes for both stress and non-stress environments.

Relationship between genotypes and resistance to drought was used as a biplot for identification of drought tolerant landraces (Fig. 3). Biplot diagram showed that the first component was higher and the second component was lower for genotypes 8, 18, 15,3 and 6. Thus, selection of these landraces with high PC_1 and low PC_2 are suitable for both rainfed and irrigation conditions (Fig. 2). Sio-Se Mardeh et al. [37] and Golabadi et al. [35] obtained similar results in multivariate analysis of drought tolerance in different crops.

2- Ranking method

The estimates of *in vivo* indicators of drought tolerance (Table 2) indicated that the identification of drought-tolerant genotypes based on a single criterion was contradictory. Different indices introduced different landraces as drought tolerant.

To determine the most desirable drought tolerant genotype according to the all indices, mean

rank and standard deviation of ranks of all *in vivo* drought tolerance criteria were calculated and based on these two criteria the most desirable drought tolerant genotypes were identified. In consideration to all indices, genotypes (15=WC-47615), (3=Phishtaz) and (6= WC-47632) exhibited the best mean rank and low standard deviation of ranks in stress condition, hence they were identified as the most drought tolerant genotypes, while genotypes (10= WC-47617), (11= WC-47637) and (4= Pishgam) as the most sensitive, hence they are recommended to be used as parents for genetic analysis, gene mapping and improvement of drought tolerance in common wheat.

Table 1. Genotype codes

Genotype	Code	Genotype	Code
WC-47536	1	WC-47637	11
WC-47620	2	WC-47400	12
Phishtaz	3	WC-47473	13
Pishgam	4	WC-47371	14
WC-47374	5	WC-47615	15
WC-47632	6	WC-47388	16
WC-47358	7	WC-5050	17
WC-4987	8	WC-47359	18
WC-5045	9	WC-47619	19
WC-47617	10	WC-47379	20

Table 2. Ranks (R), ranks mean ($\bar{R}$) and standard deviation of ranks (SDR) of drought tolerance indicators

Genotypes	Y_S	R	Y_P	R	STI	R	GMP	R	MP	R	SSI	R	TOL	R
1	0.65	5	0.76	16	0.76	8	0.72	8	0.72	9	0.92	15	0.15	18
2	0.55	10	0.78	11	0.64	13	0.66	13	0.67	13	0.78	8	0.23	13
3	0.72	3	0.82	7	0.88	4	0.77	4	0.77	6	1.03	17	0.09	20
4	0.49	17	0.72	18	0.52	18	0.59	18	0.61	18	0.67	3	0.23	14
5	0.53	13	0.95	6	0.75	10	0.71	10	0.74	7	0.83	11	0.41	3
6	0.63	7	0.82	8	0.76	9	0.72	9	0.73	8	0.90	14	0.19	15
7	0.55	11	0.98	4	0.80	5	0.73	5	0.77	5	0.86	13	0.43	2
8	0.65	6	1.02	2	1.00	3	0.81	3	0.84	3	1.03	18	0.37	4
9	0.5	16	0.73	17	0.55	17	0.61	17	0.62	17	0.70	4	0.23	11
10	0.44	20	0.67	20	0.44	20	0.55	20	0.56	20	0.59	1	0.23	12
11	0.46	19	0.7	19	0.48	19	0.57	19	0.58	19	0.63	2	0.25	10
12	0.51	15	0.8	10	0.61	15	0.64	15	0.66	14	0.73	6	0.29	5
13	0.53	14	0.78	12	0.62	14	0.65	14	0.66	15	0.76	7	0.25	9
14	0.49	18	0.77	13	0.57	16	0.62	16	0.64	16	0.70	5	0.28	6
15	0.8	1	0.98	5	1.16	2	0.89	1	0.89	2	1.23	20	0.18	17
16	0.58	8	0.77	14	0.67	12	0.67	12	0.68	12	0.82	9	0.19	16
17	0.67	4	0.77	15	0.77	7	0.72	7	0.72	10	0.94	16	0.11	19
18	0.76	2	1.03	1	1.17	1	0.88	2	0.90	1	1.20	19	0.26	7
19	0.54	12	0.99	3	0.80	6	0.73	6	0.77	4	0.85	12	0.45	1
20	0.57	9	0.82	9	0.69	11	0.68	11	0.70	11	0.82	10	0.25	8

Table 2 continued.

Genotypes	YI	R	YSI	R	DRI	R	DI	R	SSPI	R	RDI	R	ATI	R
1	1.12	6	0.87	6	1.5574	3	0.9568	5	0.92	3	1.2262	3	0.0539	3
2	0.95	11	0.75	13	0.3803	7	0.6675	10	0.78	7	1.0109	8	0.105	10
3	1.25	3	0.97	4	1.5945	2	1.0881	2	1.03	1	1.2588	1	0.0535	2
4	0.84	17	0.65	18	-0.1861	13	0.5739	13	0.67	8	0.9757	11	0.0953	8
5	0.93	12	0.80	10	-0.7825	16	0.5089	18	0.83	18	0.7998	19	0.2078	17
6	1.09	7	0.86	7	0.2612	9	0.833	6	0.90	5	1.1015	5	0.0952	7
7	0.95	10	0.83	8	-1.0189	19	0.5312	16	0.86	19	0.8046	18	0.2201	19
8	1.12	5	0.98	3	0.1757	11	0.7129	8	1.03	17	0.9136	16	0.2101	18
9	0.87	16	0.68	16	-0.461	15	0.5894	12	0.70	9	0.982	10	0.0969	9
10	0.76	20	0.58	20	-0.204	14	0.4973	20	0.59	10	0.9415	14	0.0871	4
11	0.79	19	0.61	19	-0.107	12	0.5202	17	0.63	11	0.9421	13	0.0949	6
12	0.88	15	0.71	15	-0.836	17	0.5595	14	0.73	16	0.914	15	0.1291	15
13	0.93	14	0.73	14	0.2038	10	0.6198	11	0.76	12	0.9742	12	0.1121	12
14	0.86	18	0.68	17	-0.8938	18	0.5366	15	0.70	15	0.9123	17	0.1199	14
15	1.39	1	1.15	1	2.0791	1	1.124	1	1.23	4	1.1703	4	0.1111	11
16	1.01	8	0.78	11	0.8512	6	0.7519	7	0.82	6	1.0799	6	0.0885	5
17	1.16	4	0.88	5	1.1061	4	1.0034	3	0.94	2	1.2475	2	0.05	1
18	1.32	2	1.12	2	0.8812	5	0.9651	4	1.20	14	1.0579	7	0.1666	16
19	0.93	13	0.82	9	-1.1172	20	0.5069	19	0.85	20	0.782	20	0.2294	20
20	0.98	9	0.78	12	0.32	8	0.6819	9	0.82	13	0.9966	9	0.1192	13

Table 2 continued.

Genotypes	SNPI	R	K_1STI	R	K_2STI	R	$\overline{R}$	RS	SDR
1	1.5945	4	0.8324	16	1.2516	5	7.82	12.99	5.17
2	1.105	10	0.8767	11	0.8961	10	10.47	12.56	2.09
3	1.8545	1	0.969	7	1.5357	3	5.11	10.51	5.40
4	0.9635	17	0.747	18	0.7112	17	14.47	19.02	4.55
5	0.9763	16	1.3006	6	0.8321	13	12.05	16.86	4.81
6	1.346	6	0.969	8	1.1757	7	8.05	10.77	2.72
7	1.0107	12	1.384	4	0.8961	11	10.64	16.58	5.94
8	1.2421	7	1.4993	2	1.2516	6	7.76	13.67	5.91
9	0.9867	14	0.7679	17	0.7406	16	13.70	17.56	3.86
10	0.8561	20	0.6469	20	0.5735	20	16.17	22.31	6.14
11	0.8944	19	0.7061	19	0.6268	19	15.35	20.74	5.39
12	0.9767	15	0.9223	10	0.7705	15	13.35	16.81	3.46
13	1.0421	11	0.8767	12	0.8321	14	12.17	14.29	2.12
14	0.9393	18	0.8544	13	0.7112	18	14.88	18.79	3.91
15	1.8174	2	1.384	5	1.8959	1	4.64	10.47	5.83
16	1.2165	8	0.8544	14	0.9965	8	9.52	12.83	3.31
17	1.6971	3	0.8544	15	1.3298	4	7.11	12.8	5.69
18	1.5668	5	1.5289	1	1.711	2	5.35	11.01	5.66
19	0.9886	13	1.4124	3	0.8638	12	11.35	18.09	6.74
20	1.1373	9	0.969	9	0.9624	9	9.94	11.53	1.59

Table 3. Correlation coefficients between drought tolerance indices

	Ys	Yp	TOL	MP	GMP	STI	YI	YSI	SSI	DI	K_1STI
Ys	1										
Yp	0.555*	1									
TOL	-0.376	0.558*	1								
MP	0.864**	0.897**	0.140	1							
GMP	0.920**	0.835**	0.015	0.991**	1						
STI	0.910**	0.841**	0.030	0.990**	0.996**	1					
YI	0.999**	0.557*	-0.375	0.865**	0.921**	0.911**	1				
YSI	0.964**	0.752**	-0.123	0.964**	0.990**	0.987**	0.965**	1			
SSI	0.971**	0.733**	-0.150	0.957**	0.986**	0.982**	0.972**	0.999**	1		
DI	0.928**	0.210	-0.685**	0.617**	0.710**	0.693**	0.926**	0.798**	0.814**	1	
K_1STI	0.545*	0.999**	0.567**	0.891**	0.827**	0.838**	0.546*	0.745**	0.726**	0.197	1
K_2STI	0.997**	0.546*	-0.385	0.856**	0.914**	0.909**	0.996**	0.961**	0.968**	0.977**	0.538*
RDI	0.662**	-0.249	-0.928**	0.201	0.320	0.297	0.659**	0.443	0.468*	0.892**	-0.262
ATI	-0.082	0.782**	0.949**	0.429	0.312	0.329	-0.081	0.180	0.153	-0.443	0.790**
SSPI	-0.362	0.574**	0.995**	0.155	0.030	0.047	-0.360	-0.106	-0.134	-0.678**	0.583**
SNPI	0.938**	0.280	-0.615**	0.665**	0.749**	0.728**	0.937**	0.826**	0.840**	0.989**	0.267
DRI	0.788**	0.000	-0.775**	0.416	0.524*	0.512*	0.785**	0.626**	0.648**	0.922**	-0.007

Table 3 continued

	K_2STI	RDI	ATI	SSPI	SNPI	DRI
K_2STI	1					
RDI	0.660**	1				
ATI	-0.092	-0.791**	1			
SSPI	-0.369	-0.931**	0.957**	1		
SNPI	0.934**	0.851**	-0.368	-0.609**	1	
DRI	0.794**	0.910**	-0.586**	-0.776**	0.883**	1

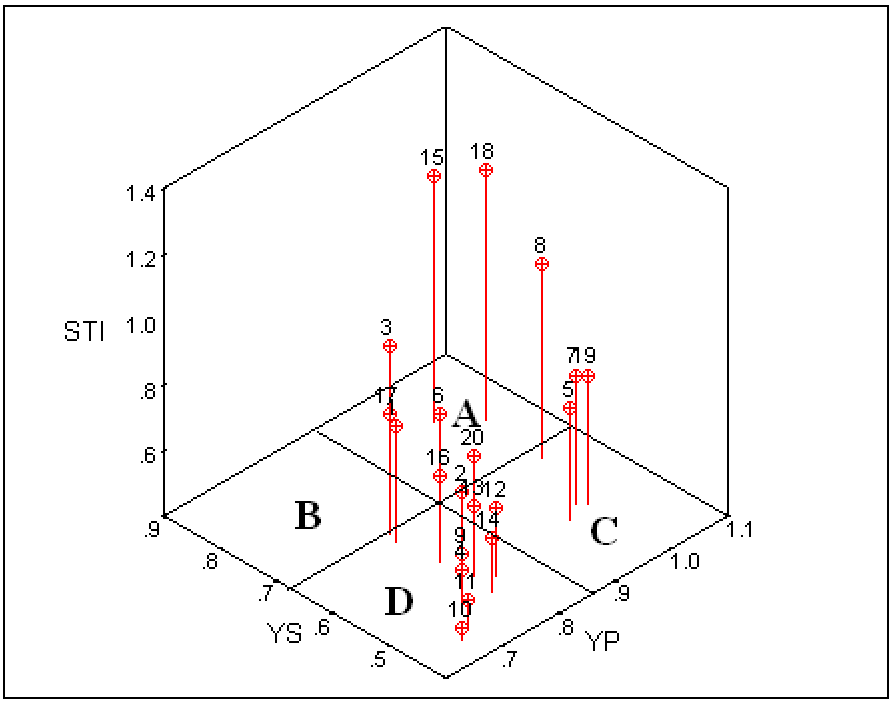

Fig.1. Three-dimensional plot between Yp, Ys and STI

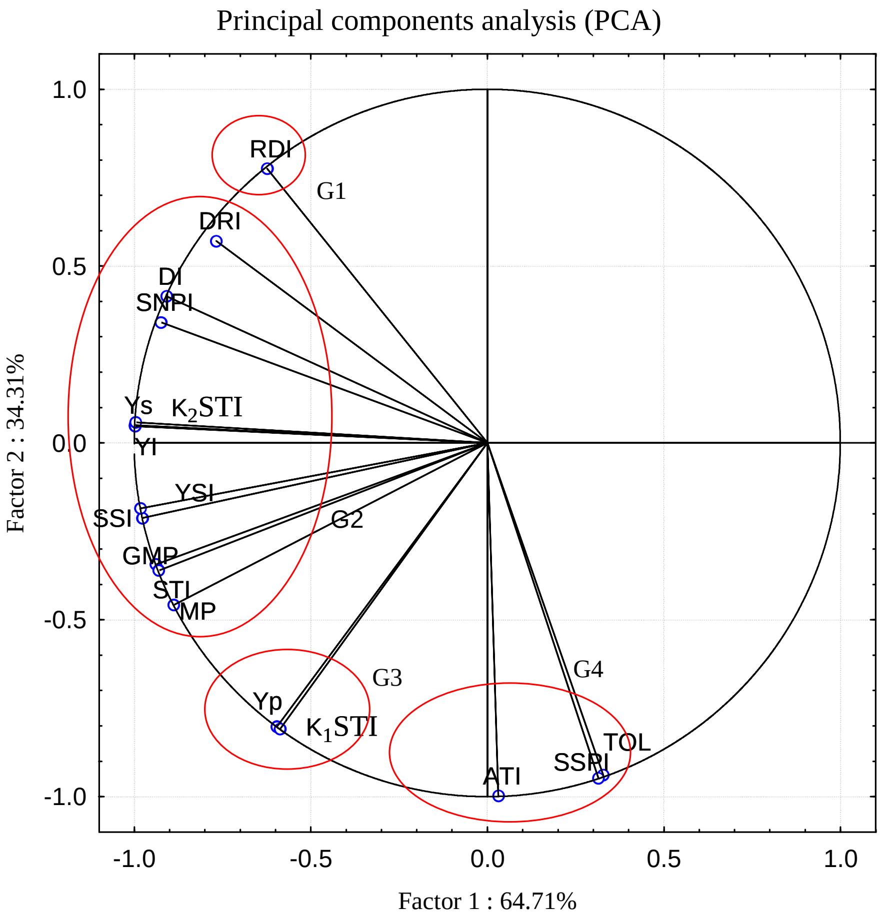

Fig. 2. Screening drought tolerance indicators using biplot analysis.

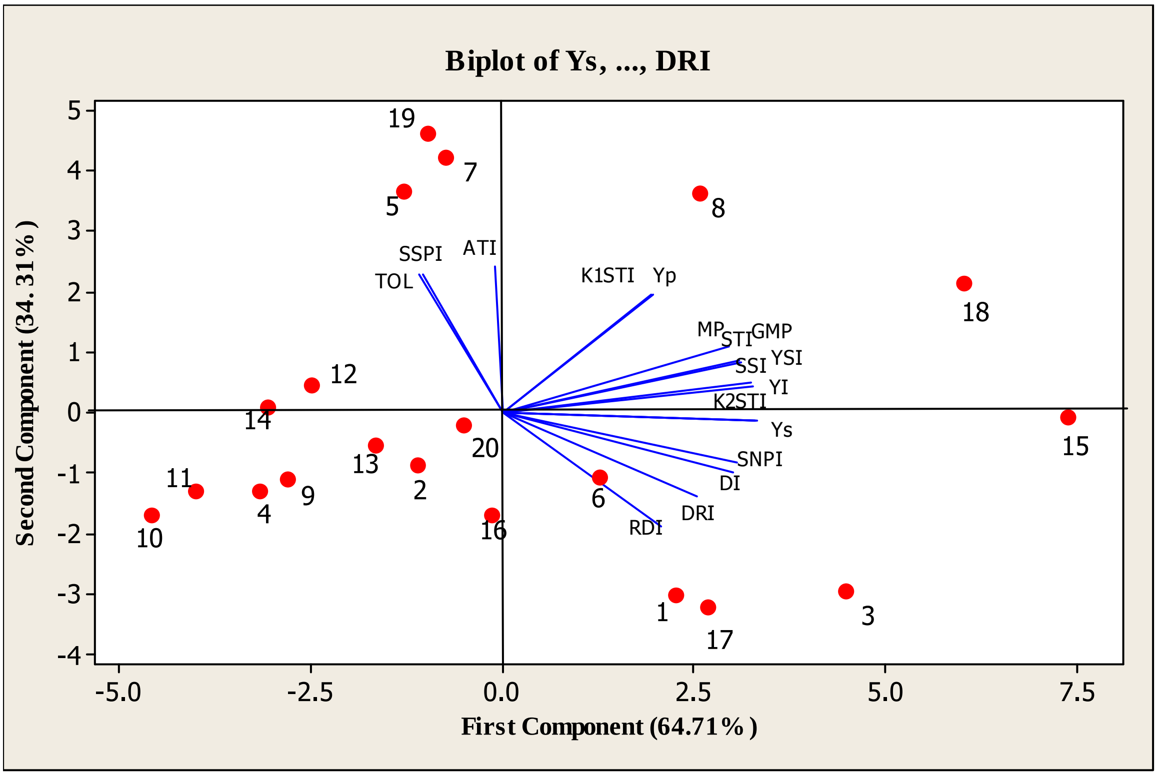

Fig. 3. Biplot based on first and second components of drought tolerance indices.

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