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ORIGINAL ARTICLE

Evaluation the Quantitative Indices of Drought Tolerance in Spring Safflower

Younes Rameshknia, Tahmasebpoor Behnam* and **Elnaz Sabbagh Tazeh
Higher Educational Institute of Rab-Rashid, Tabriz, Iran
Department of Agronomy and Plant Breeding ,Faculty of Agricultural Engineering and Technology ,
Collage of Agriculture and Natural resources, University of Tabriz , Tabriz , Iran
**Islamic Azad University ,Tabriz branch,Iran
Email: tahmasbpor@yahoo.com

ABSTRACT
Due to the growing demand for edible oils, oilseed crop development is very important. Safflower (Carthamus tinctorius L) is a native of Iran oil seed. This crop is compatible with the environmental conditions in the country as well; this is especially true in areas exposed to non-biological stresses such as drought and salinity. Since the recognition of stress- resistant varieties and grouping them is important for correct planning in plant breeding programs, this study was conducted in order to grouping safflower varieties in three irrigation regimes of stress (six and five irrigation, respectively) and free stress (seven times irrigation) conditions. This research was in split- plot form with completely random block designs about 26 varieties of safflower. The study showed the most sensitive varieties in both water stress levels and the most tolerated varieties to this condition regarding the stress tolerance index (STI) that were Zargan local IV variety, Mianeh I and N51016, respectively. Also N51016 had the most values of indices like MP, GMP and STI. According to the results, we can say under both environmental conditions, STI, MP and GMP could recognize tolerant and sensitive varieties better. So we can use these results for the selection of tolerant verities to drought regarding the breeding purposes of spring safflower. The results of simple correlations show that two indices, Yp and Ys have the most positive and significant correlation with STI, MP and GMP under both stress conditions. While the correlation between Ys with TOL and SSI was negative and significant under both conditions. So we can conclude that STI, GMP is the best indices for evaluation and recognition of under drought varieties in breeding programs.
Key words: *quantities indices, tolerant to drought, spring safflower*

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INTRODUCTION

The major portion of the oil supply is from external sources and regarding the growth of population and per capita consumption of oil in the country, increasing the area under cultivation and production of oilseeds is of utmost importance. Safflower is a native of Iran oil seed that is compatible with the environmental conditions in the country as well; this is especially true in areas exposed to non-biological stresses such as drought and salinity [23]. Despite this plant is Iran native crop and its wild species are found in abundance in Iran [1, 14] but very few studies had done about it and it is not adequately been considered. In Iran the average seed yield is 500 kg per hectare that is less than the world average (795kg ha). [6]. Safflower has the potential of 4t per hectare as can be seen 4/5 t per hectare in some experiments. Anyway 2 ton per hectare is desirable [14]. Safflower oil contains about 90% of unsaturated acids and is considered one of the best edible oils. Approximately there is 272mg tocopherol per 1 kg safflower oil that makes oil stability at elevated temperatures [4,15].
Zoop et al [24] investigated 4 safflower varieties with different periods of the grain filling that there is a positive and significant correlation between the filling period of grain and the days to flowering, the days to maturity and the grain yield. According to Tivari Vena Meduo [22] the existence difference between 1000 grain weights is from the different length of the grain filling period, different climate and the difference between the sowing and so on. Snadel et al [5] investigated different varieties of safflower and

the effects of environmental factors on the grain yield and announced that there is a positive correlation between the safflower grain yield and rainfall, the low temperature in bud formation up to flowering and the flowering to maturity and a negative correlation with high temperature and two abovementioned steps. Also the grain oil rate has a positive relationship with rainfall and low temperature in flowering period to maturity and a negative relationship with high temperature in budding period to flowering.

Matoor et al [13] investigated the different traits varieties and found out that there is a significant difference between the number of the days to flowering start up, number of sub branches, number of heads per plant and 1000 grain weight. Barzegar and Rezaei [2] reported a vast variety of 100 grain weight.

One of the critical issues in evaluating varieties for drought resistance is the quantity measurement of draught resistance parameters [3]. In semi-arid areas where rainfall distribution is not appropriate, high yield in stress condition is not the best measure of drought resistance but the performance sustainability (compared to the performance of normal and stressful conditions) is accepted as a better indicator of the reaction of genotypes to moisture stress [18]. Different indices had been used for the evaluation of genotypes reaction in the environmental conditions and their resistance and sensitivity defining. Rozveil and Humblein [17] introduced the tolerant indices (TOL) and the mean usage indices (MP). The TOL high value showed the relatively high sensitivity of genotypes to the stress. Fisher and Morrer [8] suggested the sensitivity indices to the stress (SSI). The low SSI shows the few changes of a genotype yield under both conditions. Fernandez [7] suggested GMP is the mean geometry yield of a genotype in desired and stress conditions. This index has high correlation with STI [7].

The purpose of this experiment in terms of the selection of superior varieties has different traits under different conditions of drought.

METHODS AND MATERIALS

This experiment was conducted in Azerbaijan-e-Shargi Agricultural and investigation centre as spring, in 1379. The area is located at an altitude of 1350 meters above sea level. In this study 26 spring varieties of safflower were investigated in split- plot form with completely random block designs: . ،MIAEL.1 ، MARAND L.1 ،MIANE L.2 ،MARAND L.2 ،MARAND L.3 ،LANGARMAHAN L. ،ZARGHAN L.2 ،ZARGHAN L.3 ، ZARGHAN L.4 ،ZARAND.KERMAN 1 ،ZARAND.KERMAN 2 ،KORDESTAN 2 ،ESFAHAN L. ،BROOJERD L. ، NISHABOOR L. ،N974051 ،N51016 ،V-51-242 ،NEBRASKA825 ،A-1 ،TOMJIC ،N.5 ،3151 ،24-1 و D51-361. Three different levels of irrigation mentioned as factor A. The preparing of the ground was done as: plow, disc, tabulation and stack atmosphere in spring and winter. All operations were performed in a mechanical way to deal with weeds and for a farm pest; the spraying was done three times. So that the first time was with Thrips, the second with Desis and the third one was with DinoKarp spraying pesticides. During the harvesting, in a3 irrigation level, seven times, a2: six times and a1, five times irrigation had been done. The above mentioned seven times were: after the planting, germination, the stem rapid growth, branching, 50% budding, 50% flowering and water grain. The studied traits were: the number of the harvesting days to germination, planting to stem appearance, planting to 50% budding, planting to 50% flowering, the bush height, the number of the boll per bush, the number of the grain per boll, 1000 grain weight, the grain yield and the oil percentage.

After making sure that the assumptions of the analysis of variance, the analyzed data and the means by LSD test were compared in 1 and 5% possibility levels. To determine the sensitivity rate or the genotype tolerance to drought, we used TOL, MP, SSI, GMP and STI in this way:

$$TOL = Y_p - Y_s$$

$$MP = \frac{Y_s + Y_p}{2}$$

$$SSI = \frac{1 - \frac{Y_s}{Y_p}}{1 - \frac{\bar{Y}_s}{\bar{Y}_p}}$$

$$GMP = \sqrt{Y_s . Y_p}$$

$$STI = \frac{Y_p . Y_s}{(\bar{Y}_p)^2}$$

Yp: the yield under stress free condition

Ys: the yield under stress

$\bar{Y}_S$: The mean of all genotype yields under stress

$\overline{Y}_p$: The mean of all genotype yields under stress- free conditions

RESULTS AND DISCUSSION

Evaluation of the varieties on the basis of drought tolerance indices

TOL is one of the most important indicators of drought resistance indices which low values shows more resistance of that for a stress. According to this index, under severe stress of water shortage, the most tolerant cases were: Kerman Zarand1, Kerman Zarand2, N974051, and N51016 and A-1. The most sensitive cases were: Mianeh local2, Zaragan local4 and Kordestan local2 (table1 and figure1). According to this index, under mild stress, Kerman Zarand1, Kerman Zarand2, N974051, N51016, N5 and Bonab local were the most tolerant and V-51-242 was the most sensitive (table2 and figure2). MP is another index that its high value shows that variety's more resistance to the stress. According to this index, under severe stress, N51016 and TOMJIC were the most tolerant cases (table1 and figure3). Under mild stress, N51016 were the most tolerant (table2 and figure4). According to GMP, N51016 and TOMJIC had more tolerance under severe stress and N51016 with Marand local3 had the most resistance under mild stress. But according to this index, Mianeh local1 was the most sensitive one under both conditions (tables1 and 2, figures 5 and 6).

SSI is another index that on the basis of it, under both conditions, Zargan local4 was the most sensitive case (tables1 and 2, figures 7 and 8).

The last index is STI which shows N51016 is the most tolerant case under both conditions (tables 1 and 2, figures 9 and 10).

Above mentioned contents show that under both environmental conditions, MP, GMP and STI could recognize the tolerant and sensitive varieties better. Richard (16) believed that the genotypes selection under both stress and stress-free conditions cause the accumulation of favorable alleles and we can choose the genotypes with high yield. Fernandez (7) announced that STI can select the genotypes with high performance under both environments. Sondari et al [20] introduced MP, GMP and STI as the best indices for the tolerance to the stress. Also Kargar et al (11) could recognize GMP and STI as the most appropriate index for the selection of studied genotypes in soya. Siose Morde et al [19] in the investigation of rain fed wheat varieties reported that SSI is the most appropriate index for the selection of tolerant varieties to drought and MP, GMP and STI were the best indices for mild stress condition.

Table1. Levels of drought resistance indices based on grain yield in studied spring safflower under extreme stress.

Variety	TOL	MP	GMP	SSI	STI
Bonab local	3/48	15/68	15/58	1/47	0/71
Mianeh 1local	7/27	13/02	12/50	3/22	0/46
Marand1 local	2/46	16/62	16/57	1/02	0/78
Mianeh2 local	8/45	17/63	17/11	2/85	0/86
Marand2 local	0/82	18/21	18/20	0/32	0/94
Marand3 local	4/11	18/83	18/72	1/45	1/02
Langar Mahan	1/92	18/06	18/04	0/74	0/97
Zargan2 local	3/86	14/73	14/60	1/71	0/63
Zargan3 local	1/46	18/67	18/65	0/56	1/02
Zargan4 local	8/14	13/42	12/79	3/44	0/48
Kerman Zarand1	0	16/08	16/00	0	0/73
Kerman Zarand2	0	15/62	15/60	0	0/71
Kordestan2 local	7/46	16/40	15/97	2/74	0/74
Isfahan local	4/26	16/31	16/17	1/71	0/75
Borojerd local	1/94	16/68	16/65	0/81	0/81
Neishaboor local	2/33	18/16	18/12	0/89	0/96
N974051	0	19/66	19/62	0	1/14
V-51-242	2/71	19/59	19/55	0/95	1/08
NEBRASKA	2/2	16/28	16/24	0/94	0/76
A-1	0	19/63	19/63	0	1/13
TOMJIC	0/2	20/18	20/17	0/07	1/21
N.5	3/07	14/16	14/07	1/45	0/58
3151	0/81	19/36	19/35	0/30	1/08
D51-361	0/86	15/69	15/69	0/39	1/08
24-1	5/38	17/82	17/58	2/08	0/91

Table2. The means of drought resistance indices in studied spring safflower cultivars based on grain yield under mild stress conditions.

Variety	TOL	MP	GMP	SSI	STI
Bonab local	0/32	17/26	17/26	0/16	0/88
Mianeh 1local	2/46	15/42	15/37	1/27	0/69
Marand1 local	2/83	16/43	16/37	1/37	0/80
Mianeh2 local	4/45	19/63	19/5	1/75	1/12
Marand2 local	2/56	17/34	17/29	1/18	0/89
Marand3 local	1/81	19/98	19/96	0/74	1/18
Langar Mahan	2/53	17/76	17/71	1/15	0/95
Zargan2 local	1/07	16/12	16/11	0/55	0/76
Zargan3 local	4	17/40	17/28	1/78	0/89
Zargan4 local	4/59	15/20	15/02	2/26	0/67
Kerman Zarand1	0	15/93	15/86	0	0/75
Kerman Zarand2	0	17/23	17/08	0	0/85
Kordestan2 local	4/59	17/83	17/68	1/96	0/89
Isfahan local	0/29	18/29	18/29	0/13	1/02
Borojerd local	3/94	15/68	15/55	1/92	0/74
Neishaboor local	3/16	17/75	17/67	1/41	0/92
N974051	0	18/49	18/49	0	1
V-51-242	7	17/45	17/09	2/88	0/87
NEBRASKA	1/19	16/78	16/77	0/59	0/83
A-1	2/18	18/46	18/43	0/96	1/01
TOMJIC	2/81	18/87	18/82	1/19	1/05
N.5	0	15/75	15/75	0	0/71
3151	3/2	18/16	18/09	1/39	0/95
D51-361	4/22	14/01	13/85	2/25	0/56
24-1	4/88	18/29	18/13	2/03	0/97

Order of varieties in horizental axes(x axes) of Figures

Variety	Number of varieties in horizental axes(x axes) of Figures
Bonab local	1
Mianeh 1local	2
Marand1 local	3
Mianeh2 local	4
Marand2 local	5
Marand3 local	6
Langar Mahan	7
Zargan2 local	8
Zargan3 local	9
Zargan4 local	10
Kerman Zarand1	11
Kerman Zarand2	12
Kordestan2 local	13
Isfahan local	14
Borojerd local	15
Neishaboor local	16
N974051	17
V-51-242	18
NEBRASKA	19
A-1	20
TOMJIC	21
N.5	22
3151	23
D51-361	24
24-1	25

Figure1. TOL coefficients in a1 to a3 for 26 spring safflower

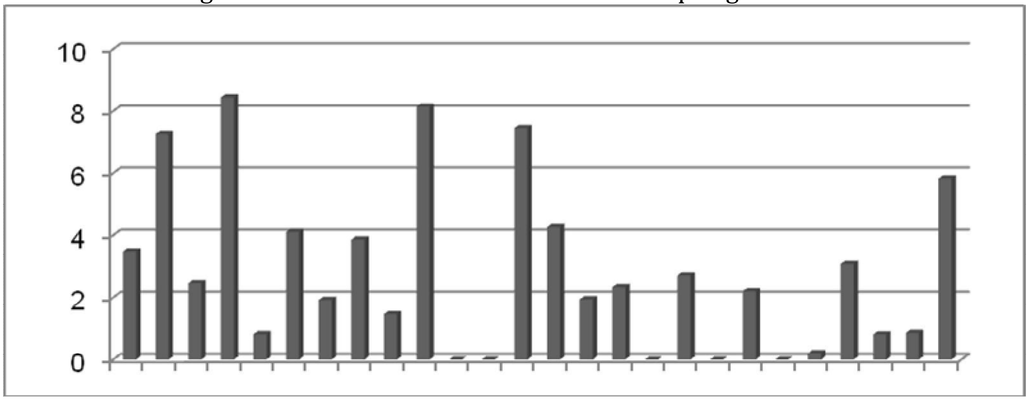


Figure2. TOL coefficient in a2 to a3 for 26 spring safflower

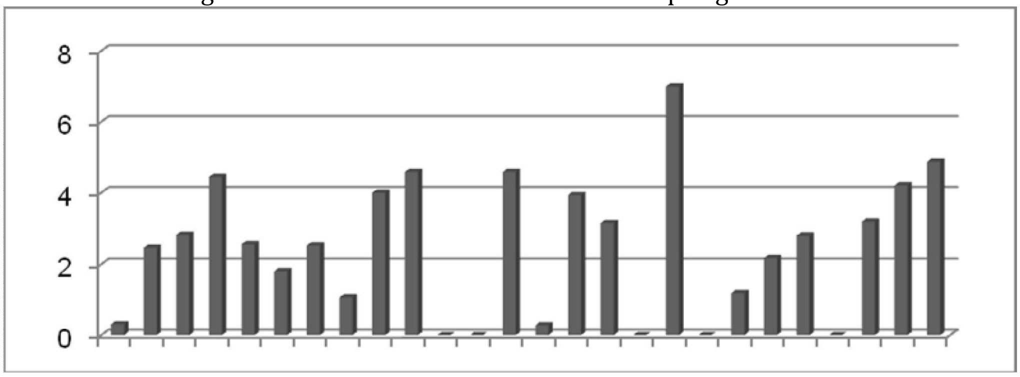


Figure3. MP coefficients in a1 to a3 for 26 spring safflower

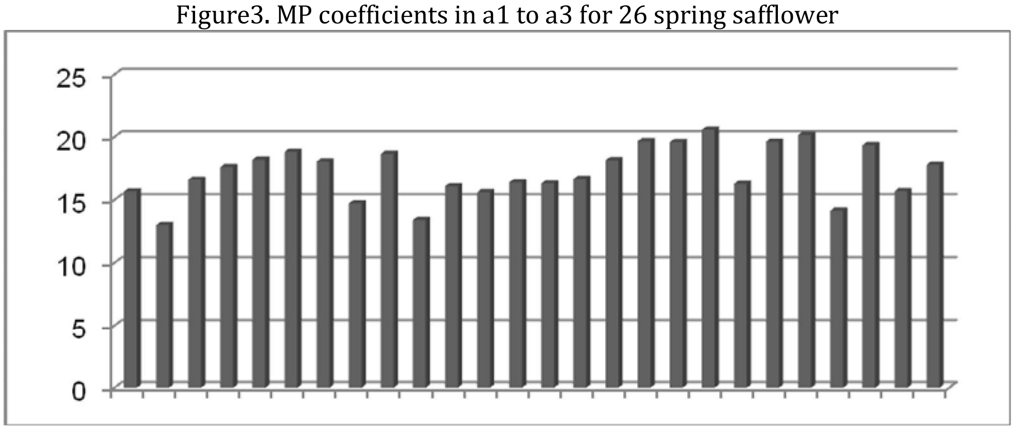


Figure4. MP coefficients in a2 to a3 for 26 spring safflowers

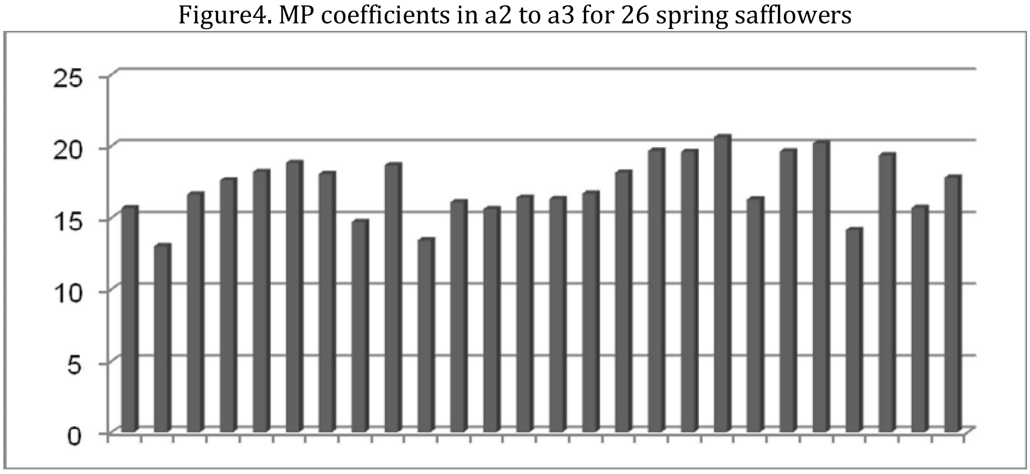


Figure5. GMP coefficients in a1 to a3 for 26 safflowers

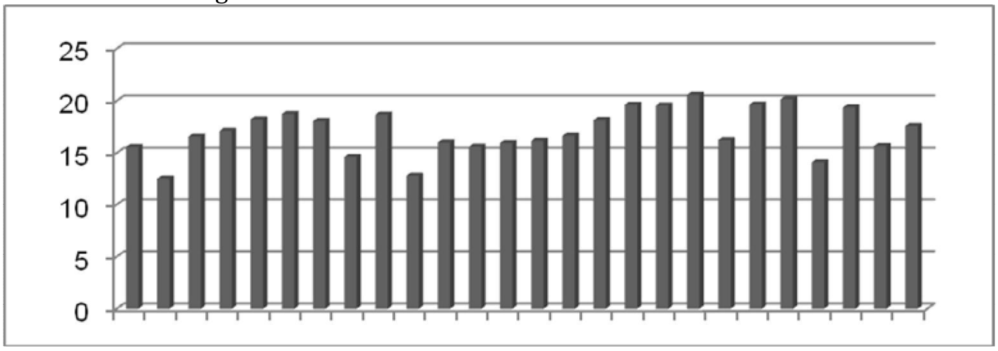


Figure6. GMP coefficients in a2 to a3 for 26 spring safflowers

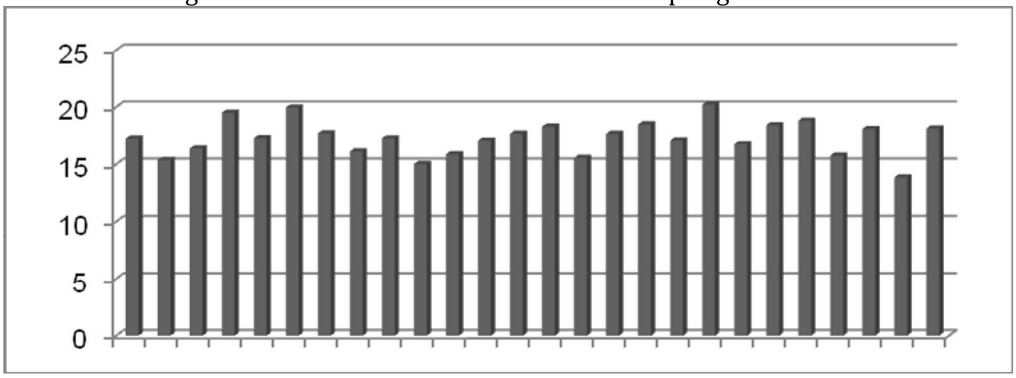


Figure7. SSI coefficients in a1 to a3 for 26 spring safflowers

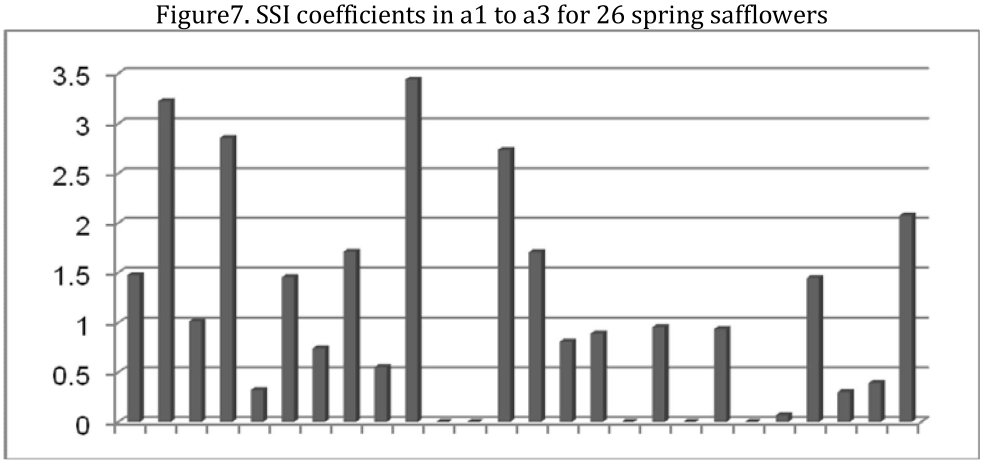


Figure8. SSI coefficients in a2 to a3 for 26 spring safflower

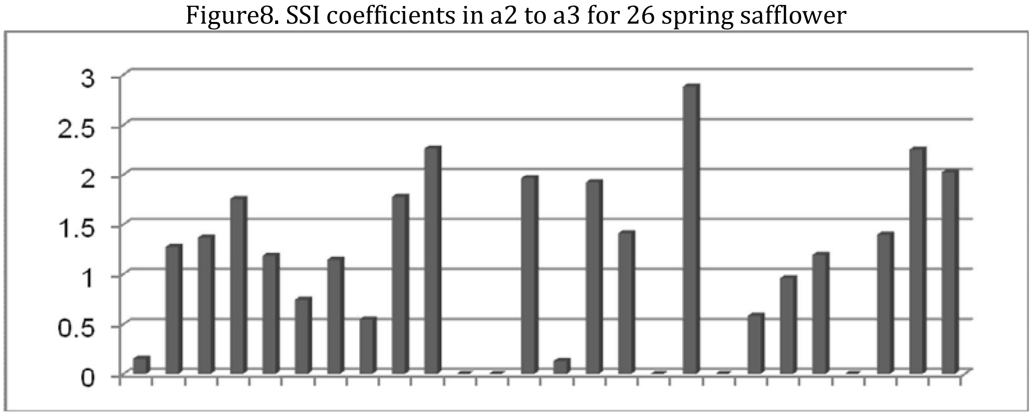


Figure9. STI coefficients in a1 to a3 for 26 spring safflowers

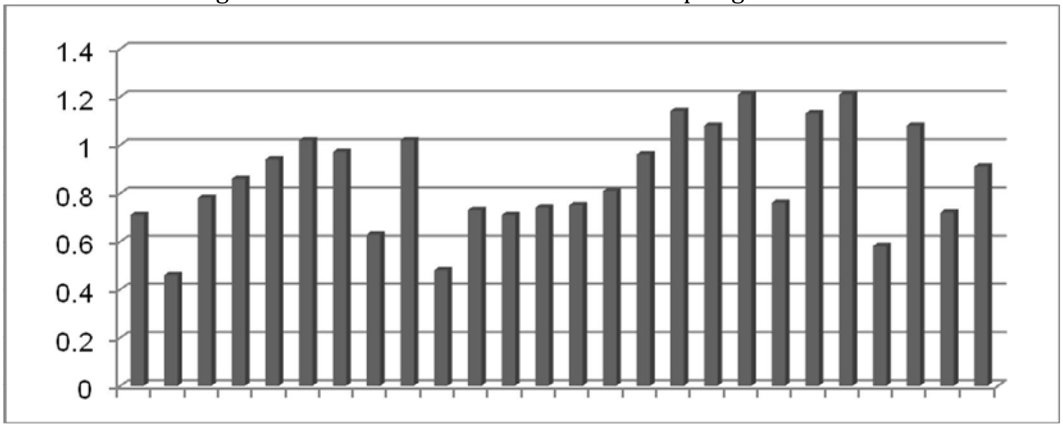
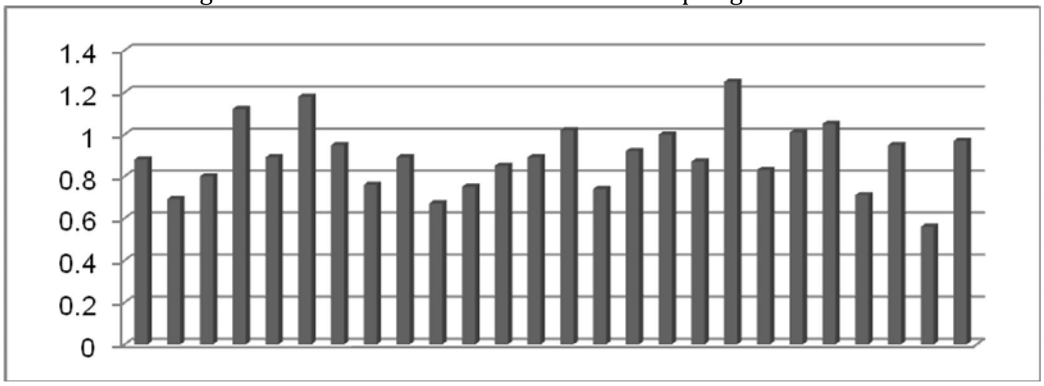


Figure10. STI coefficients in a2 to a3 for 26 spring safflowers



The correlation between the drought tolerant indices

The simple correlation coefficient between the droughts tolerant indices under severe (a1) and mild (a2) drought stress in spring safflowers are in table 3 and 4 respectively. We can see that under both stress conditions, Yp had a positive and significant correlation with MP, GMP and STI in 1% possibility level, but it found a positive and insignificant correlation with TOL. The correlation between Ys with MP, GMP and STI under both conditions was positive and significant and there were negative and insignificant correlation under mild stress condition. SSI and STI correlation was negative in 1% possibility level. SSI had positive and significant correlation with TOL and MP under severe stress condition but that was positive and significant with Yp and TOL.

Golabadi et al [9] reported a positive relationship between Yp and Ys with Mp and STI. Jafrai et al [10] suggested STI, MP and GMP as the most appropriate index in the corn breeding plans. Also they showed that have the high correlation with the grain yield under normal and drought stress conditions. Maleki et al [12] reported the same results about the wheat. Tagian and Abarfoa [21] reported a positive and significant correlation between Yp and Ys with STI, MP and GMP in wheat. So we can conclude that MP, GMP and STI are the most appropriate indices for evaluation and recognition of drought stress varieties to use in breeding plans.

Table3. The simple correlation coefficients between droughts tolerant indices under severe stress condition (a1)

index	Ys	Yp	TOL	MP	GMP	STI	SSI
Ys	1						
Yp	0/316	1					
TOL	-0/821**	0/235	1				
MP	0/898**	0/700**	-0/508**	1			
GMP	0/920**	0/659**	-0/561**	0/997**	1		
STI	0/917**	0/662	-0/555**	0/997**	0/997**	1	
SSI	-0/877**	0/130	0/988	0/600**	-0/649**	-0/637**	1

* And ** are the significance in 1% and 5% possibility levels, respectively.

Table4. The simple correlation coefficients between the drought tolerant indices under mild stress conditions (a2)

index	Ys	Yp	TOL	MP	GMP	STI	SSI
Ys	1						
Yp	0/181	1					
TOL	-0/655**	0/531	1				
MP	0/779**	0/758**	-0/096	1			
GMP	0/796**	0/737**	-0/138	0/999**	1		
STI	0/793**	0/738**	-0/136	0/997**	0/998**	1	
SSI	-0/737**	0/440*	0/989**	-0/208	-0/247	-0/243	1

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