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Evaluation of fenugreek (*Trigonella foenum-graecum* L.) genotypes under limited moisture stress conditions

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Abstract

A field experiment was conducted with ten fenugreek genotypes comprised of some prominent mutant line and already released varieties. The aim of this study was collection and screening of promising genotypes which have tolerance to limited moisture stress conditions during active plant growth stage. The screening criteria was based on morpho-physiological parameters including fresh weight, shoot weight, root weight, shoot length, root length, no. of branches, shoot-root length and weight ratio leaf area, water potential, canopy temperature, difference between canopy and air temperature and chlorophyll content under optimal irrigation regime and moisture stress regime at flowering and post flowering stages.

Key words : Fenugreek, limited moisture stress, stress susceptibility index, stress tolerance index, stress tolerance.

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is an annual herb belonging to the *Fabaceae* family, most cultivated and widely spread species which literally means 'Greek hay' indicating its use as forage in the past. Fenugreek is a native of South-Eastern Europe and West Asia (Petropoulos, 2002) where; it is found growing wild and has been cultivated for a long time. The Indian sub continent is thought to be secondary centre of origin due to availability of genetic diversity. Fenugreek leaves and seed are commonly used for flavouring and as a spice in curries due to their strong flavour and aroma. In addition to that Araee *et al*., (2009) and Rathore *et al*., (2013) reported a wide range of medicinal uses, including for the treatment of inflammation, tumors, cardiovascular disease, rental insufficiency infections and metabolic disorders. In India it is cultivated mainly in Rajasthan and occupies a total area of 91000 ha with an annual production of 1.11 lakh tones with a productivity of 1210 kg ha^{-1} (Anonymous, 2015).

Fenugreek can be grown under a wide range of climatic condition. It requires cool climate and dry weather is must at the time of maturity. Environmental factors such as water, temperature and nutritional status affect the morpho-physiological and biochemical responses of plants which were studied by many researchers (Vyas *et al*., 2017; Saxena *et al.,* 2017; Acharya *et al*., 2007; Chhibba *et al*., 2000).

In India, fenugreek is grown in winter season on conserved moisture and shows indeterminate type of growth habit. Fenugreek can be grown under varied climate on variety of soil types provided the soil is well drained. Climate change is influencing the availability of conserve moisture for winter season crops in North India and uncertainty of winter rains necessitates irrigation application at vegetative growth stage of fenugreek. Hence, in case of limited water availability the crop suffers moisture stress during vegetative to reproductive stage.

Unlike other legumes, fenugreek is fairly tolerant to salinity (Jakhar *et al*., 2013) while water stress during vegetative growth affects the crop growth (Alhadi *et al*., 1999; Saxena *et al*., 2017). Fenugreek however, can be grown with limited water but irrigation at suitable growth stage resulted in an increase in yield and yield contributing traits which showed significant genetic variation (Kumar *et al*., 2000; Chhibba *et al*., 2000; Acharya *et al*. 2007; Jain *et al*., 2013; Vyas *et al*., 2017; Saxena *et al*., 2017). Besides growth parameters physiological parameters including leaf area, water potential, canopy temperature, difference between canopy and air temperature and photosynthetic pigments also affected by water stress which ultimately affecting seed yield in some fenugreek varieties (Hussein and Zaki, 2013). Exploitation of genetic variability for obtaining sustainable yield in dry lands or areas with moisture deficiency is a well practiced crop improvement strategy. Hence, in present investigations a set of fenugreek genotypes have been evaluated to estimate

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the available variation in studied genotypes that can be further use in plant improvement programmes.

To differentiate the degree of drought resistance between different genotypes, several selection indices have been suggested. One of them is the stress susceptibility index (SSI) which is a ratio of genotypic performance under stress and non-stress conditions (Fischer and Maurer, 1978).

The aim of present study was to use the stress tolerance index to screen the drought tolerance of 10 fenugreek genotypes. Analysis was done on the base of morpho-physiological and yield parameters. The identified genotypes with higher drought tolerance will be use as starting material in the fenugreek drought tolerance breeding program.

Materials and methods

The experiment was conducted during Rabi season of 2016-17. The experimental field was prepared by 2-3 ploughing with cultivator and beds of 3 m × 2 m size were prepared. The seeds of ten fenugreek genotypes sown was obtained from gene bank of ICAR-NRCSS, Tabiji, Ajmer. These genotypes, comprising mutants, advance breeding lines and released varieties and were sown in triplicate with three different environments namely no water stress, midterm water stress (flowering stage) and terminal water stress (post flowering stage) at research farm area of NRCSS, Ajmer. Irrigations were given at seed sowing stage and for establishing the crop in all three environments. Till pre flowering stage which commensurate with 50-60 days after sowing all treatments were similar. At this stage moisture stress was created by withholding irrigation in one set of genotypes (midterm water stress) while other two sets were given normal irrigation. At post flowering stage which commensurate with 90 days after sowing in most of the genotypes moisture stress was created by withholding irrigation in another set of genotypes (terminal water stress) while remaining two sets were given normal irrigation. Soil of experimental block was sandy loam with moderate water holding capacity and was uniformly provided with organic manure in the form of FYM. Seeds were sown during first week of November. All standard recommended agronomic practices were carried out during entire cropping season except irrigation. Plant protection measures were also adopted as and when required.

Morphological parameters viz. fresh weight, dry weight, shoot weight, shoot length, root weight, root length, number of branches, number of pods per plant were recorded after 10 days of imposing stress. Seed yield plant^{-1} (gm) was recorded at the time of harvesting of crop.

Stress susceptibility index (SSI) was calculated for yield and other attributes over limited moisture (stress) and normal (non stress) environment as per formula given by Fisher and Maurer (1978).

$$SSI = (1 - YD / YP) / D$$

Where,

YD = Mean of the genotype in limited moisture environment

YP = Mean of the genotype in normal environment

D = Stress (limited moisture) intensity =

$$1 = \left(\frac{\text{Mean } Y_D \text{ of all genotype}}{\text{Mean } Y_P \text{ of all genotypes}} \right)$$

Stress tolerance index (STI) = [(YP) × (YD) / (YP)^2]

Stress tolerance (TOL) = (YP - YD)

Where,

YP = Yields of genotypes under normal condition

YD = Yields of genotypes under limited moisture condition

The SSI values were used to characterize the relative tolerance of genotypes based on minimization of yield losses compared to normal environmental conditions. The differences between genotypes for different characters were tested for significance by using standard techniques for analysis of variance.

Results and discussion

Growth parameters of fenugreek genotypes including seed yield plant^{-1} as affected by water stress at different growth stages have been shown in table 1. All tested genotypes showed a reducing trend in number of pods plant^{-1} under moisture stress conditions. In control conditions number of pods plant^{-1} was ranging from minimum of 32.1 in genotype B5-73-11 to maximum of 39.9 in genotype A3-31-1-17. Under midterm water stress conditions minimum number of pods plant^{-1} (20.50) was observed in genotype A3-31-1-17 while maximum (33.50) in B3-77-8-10 whereas, terminal stress had minimum of 22.6 in C4-23-1 and maximum of 29.9 in AFg-3, C4-2-14. A significant genotypic variation was observed for moisture stress conditions and genotype x environment interaction, however, it was non significant for different varieties.

In most of the genotypes SW: RW reduced in response to water stress at either growth stage as compared to control, except genotypes B5-5-6-1 and C4-2-14 which had exceptionally high ratio during midterm stress. In control conditions SW: RW ranged from a minimum of 35.2 in genotype B5-5-6-1 to a maximum of 44.3 in genotype AFg-3. Under midterm water stress conditions minimum ratio (32.70) was observed in genotype A3-31-1-17 while maximum in C4-2-14 (49.2) whereas, terminal stress had minimum ratio of 24.9 in B3-77-8-10 and maximum of 47.4 in B5-33-20. A significant genotypic variation, environment and genotype x environment interaction was observed for moisture stress on SW:RW of fenugreek genotypes (Table 1).

The studied genotypes showed reduction trend in shoot length during both the stress conditions *i.e* midterm, terminal as compared to control. In control conditions ratio ranged from minimum of 3.2 in genotype B5-33-20 to maximum of 3.5 in genotype B5-5-6-1, AFg-3 and C4-23-1. Under midterm water stress conditions minimum ratio (2.60) was observed in genotype C4-23-1, while maximum (3.5) in AFg3. Terminal stress had minimum ratio of 2.90 in A3-31-1-17and maximum of 3.2 in A3-31-2-7-2 and B5-73-11. Statistical analysis revealed a significant genotypic variation for the effect of moisture stress conditions on SL: RL. Environment and genotype x environment interactions were also statistically significant.

Under controlled condition maximum seed yield (10.30 g) was obtained in genotype AFg 3, followed A3-31-1-17 (10.10 g) and minimum (7.00 g) seed yield was obtained in genotype B5-5-6-1. Under midterm stress conditions, maximum seed yield (8.80 g) was obtained in genotype AFg 3 which is closely followed by (8.60 g) genotype C4-2-14. Minimum (3.70 g) seed yield plant^{-1} was obtained in genotype A3-31-2-7-2. Seed yield plant^{-1} was significantly reduced under terminal stress conditions, maximum (5.80 g) being observed in genotype B4-22-7-2-1and minimum (3.30 g) in genotype C4-2-14. Data showed significant genotypic, environment and GxE interaction effects of moisture stress on seed yield (Table 1).

The 10 contrasting advance line of fenugreek which were taken for present study showed considerable genotypic and phenotypic variation among morphological parameters recorded at flowering and post flowering stages. Variation observed was found statistically significant since selection of genotypes was made with a view to exploit this variation for selecting drought stress tolerant fenugreek genotypes. Genotypic variability in fenugreek has been reported previously by many researchers. Acharya *et al.,* (2006) observed considerable variability among fenugreek genotypes. Genotypes differ in morphology, growth habit, biomass and seed production capability. Malik and Tehlan (2009) evaluated sixteen fenugreek genotypes during 2005-06 and 2007-08 in Hisar, Haryana, India and recorded observations for plant height, branches plant^{-1}, pods plant^{-1}, length of pod, seeds pod^{-1} and seed yield. Significant variation was observed for all the studied characters. In The current styudy results are also in line to this where selected genotypes showed significant variations in these characters.

The plant drought response will depend on the species inherent strategy, but also on the duration and severity of the drought period. If drought stress prolonged over to a certain period, it will inevitably result in oxidative damage due to the over production of reactive oxygen species (Carvalho, 2008). In fenugreek, Spyropoulos (1986) found that growth and dry weight were lower in plants under stressed than non-stressed controls. The genotypes despite having good fresh weight could not able to convert accumulated biomass in to seeds hence; seed yield was low in stress conditions.

Effect of moisture stress on seed quality parameters were also studied and presented in table 2. In control condition maximum test weight (14.01g) was observed for the genotype C4-2-14 and minimum (9.51 g) in genotype C4-23-1. Interestingly test weight of all genotypes found to increase except genotypes A3-31-2-7-2, A3-31-1-17 and B5-73-11 under midterm stress conditions. Moisture stress at terminal growth stage was, however, reduced test weight in all tested genotypes where maximum test weight (11.62 g) was observed in genotype AFg- 3 and minimum (8.68 g) in genotype C4-23-1.

In general oil content was reduced due to moisture stress. Table 2 showed the oil percent of various genotypes of fenugreek under different environment conditions. In control condition maximum (3.27%) seed oil was extracted from genotype A3-31-2-7-2 while genotype B3-77-8-10 gave minimum seed oil yield (1.79%). Imposition of moisture stress at mid term growth stage resulted in reduction in oil percentage. The only genotype AFg-3 showed an increase from 2.8 to 3.23% under midterm stress. The oil content further reduced if moisture stress applied at terminal growth stage being observed maximum (3.14%) in genotype A3-31-1-17 and minimum (0.83%) in genotype C4-23-1. It is well known that genetic and environmental factors play an important role and can affect the oil yield and quality in terms of fatty acids composition. Water stress at different growth stages of plant might alter the seed composition and related qualities (Nel, 2001; Flagella *et al.,* 2002; Anwar *et al.,* 2006). The decrease in seed oil contents of oil seed crops under water stress is a common phenomenon (Ali *et al.,* 2009).

Most of the genotypes showed increased sapogenin under midterm as well as terminal moisture stress conditions. Under midterm stress condition maximum sapogenin (6.52%) was observed in B4-22-7-2-1 while minimum (5.25%) was recorded in genotype AFg-3 which further reduced under terminal stress conditions up to 4.56% in genotype AEg 3. While under midterm stress condition maximum diosgenin content was found to increase in most

Table 1. Growth parameters of fenugreek genotypes as affected by water stress

Genotype	No of Pods			SW:RW			SL:RL			Yield plant^{-1} (g)		
	NS	MS	TS	NS	MS	TS	NS	MS	TS	NS	MS	TS
A3-31-2-7-2	36.5	27.2	27.9	39.3	37.8	37.9	3.4	2.9	3.2	8.3	3.7	5.5
B4-22-7-2-1	33.1	31.3	26.6	56.1	41.5	38.8	3.4	3.2	3.1	6.8	7	5.8
B5-33-20	37.7	31.4	23.9	57.9	39.7	47.4	3.2	3.3	3.2	8	8.2	5.6
B5-5-6-1	35.1	31.1	26.6	35.2	47.1	36	3.5	3.2	3.1	7	7.1	4.3
AFG3	36.3	28.2	29.9	44.3	38.4	40.7	3.5	3.5	3	10.3	8.8	5.6
C4-23-1	36	28.9	22.6	63.5	39	37.1	3.5	2.6	3	9.9	4.8	3.9
B3-77-8-10	35.7	33.5	27.1	53	46.7	24.9	3.4	3.2	3.3	8.7	7.2	4
C4-2-14	33.7	32.5	29.9	44.7	49.2	38.7	3.4	3.2	3.3	8.1	8.6	3.3
A3-31-1-17	39.9	20.5	25.9	44.6	32.7	34.1	3.3	2.9	2.9	10.1	5.6	4.5
B5-73-11	32.1	25.5	27.3	55	40	34.2	3.3	3	3.2	7.8	5.7	4.2
Mean	35.61	29.01	26.77	49.36	41.21	36.98	3.39	3.1	3.13	8.5	6.67	4.67
CD V (0.05%)		N.S			10.38			0.31			2.02	
CD E (0.05%)		14.14			19.41			0.50			5.89	
CD VxE (0.05%)		9.83			21.74			0.51			4.19	
CV (%)		10.35			16.23			4.14			19.80	

NS: No stress (Control), MS: Stress at midterm growth stage (Flowering stage), TS: Terminal growth stage (Post flowering and pod filling stage)

Table 2. Seed quality parameters of fenugreek genotypes as affected by water stress

Genotype	Test weight			Oil %			Sapogenin %			Diosgenin %		
	NS	MS	TS	NS	MS	TS	NS	MS	TS	NS	MS	TS
A3-31-2-7-2	12.12	11.55	8.95	3.27	1.29	1.62	5.51	5.71	6.52	0.14	0.4	0.35
B4-22-7-2-1	11.6	12.4	10.88	2.17	2.07	1.07	5.61	6.52	6.47	0.13	0.61	0.26
B5-33-20	13.22	13.24	10.99	2.15	1.55	1.64	4.92	5.78	5.8	0.24	0.4	0.23
B5-5-6-1	12.61	13.34	10.35	1.98	1.9	0.83	5.44	5.82	6.51	0.25	0.37	0.18
AFG3	13.77	15.49	11.62	2.8	3.23	1.95	4.92	5.25	4.56	0.28	0.41	0.13
C4-23-1	9.51	9.82	8.68	2.61	1.48	1.3	5.84	6.08	6.03	0.14	0.31	0.06
B3-77-8-10	12.36	12.4	10.35	1.79	1.49	2.64	5.89	5.88	5.99	0.1	0.35	0.11
C4-2-14	14.01	15.34	10.95	2.81	0.97	2.27	4.97	6.02	6.23	0.33	0.39	0.08
A3-31-1-17	13.67	12.78	10.33	2.32	2.1	3.14	5.73	5.66	6.22	0.36	0.29	0.12
B5-73-11	12.37	12.29	9.91	2.65	1.11	2.15	5.77	5.72	6.26	0.33	0.33	0.07
Mean	12.524	12.865	10.301	2.455	1.719	1.861	5.46	5.844	6.059	0.23	0.386	0.16

NS: No stress (Control), MS: Stress at midterm growth stage (Flowering stage), TS: Terminal growth stage (Post flowering and pod filling stage) of the genotypes except genotype A3-31-1-17 where it reduced from 0.36 to 0.26%. Under terminal stress condition diosgenin content showed reduction in most of the genotypes except A3-31-2-7-2 and B4-22-7-2-1.

The seeds of fenugreek have long been known as a traditional medicine, having hypocholesterolemic and antidiabetic effects (Mishkinsky *et al.*, 1974; Singhal *et al.*, 1982). The hypocholesterolemic activity is related to the defatted part of the seed extract (Valette *et al.*, 1984) and involves saponin rich subfractions (Sauvaire *et al.*, 1991). It is important to explore alternative food and non-food sources of saponins due to increasing evidence of their health benefits. Several researchers evaluated fenugreek germplasm for sapogenin and diosgenin content. Similar to present study Taylor *et al.*, (2002) found diosgenin levels from mature seeds ranged from 0.28 to 0.92% (28-92 ìg/10 mg). In an another study Arivalagan *et al.*, (2013) reported steroidal saponins and fixed oil content in fenugreek genotypes in the range of 0.92 g to 1.68 g and 3.25 to 6.88 g with corresponding mean value of 1.34 g and 5.19 g/100 g dw, respectively. Environment-wise analysis of variance revealed that significant differences existed among genotypes in each environment for all characters indicating that real differences existed among the genotypes. Genotype x environment interaction was not significant for all the traits.

The inherent potential of crop cultivars to perform well in drought-stressed environments is imperative for sustainable crop production. The relative performance of genotypes in drought-stressed and non-stressed environments can be used as an indicator to identify drought-resistant varieties for drought-prone environments. Several drought indices have been suggested on the basis of a mathematical relationship between yield under drought conditions and non-stressed conditions. These indices are based on either drought resistance or drought susceptibility of genotypes (Raman *et al.*, 2012). Drought tolerance is expressed by the stress susceptibility index (SSI). Various results were obtained based on the screening of genotypes grown under optimal and dry conditions. As a measure of stress susceptibility, based on SSI, genotypes having different drought tolerance level were determined. Stress susceptibility (<1) is synonymous of higher stress resistance. In the present study the differences in performance of genotypes in two environments indicates the effect of limited moisture stress on different character was not uniform, thus some of characters were influenced more while other less. It is well established that yield is a complex trait controlled by several characters. Thus, a selection based exclusively on yield will not be effective. Therefore, stress susceptibility index was worked out based on values of different yield attributes and seed quality parameters separately used in the study. Limited moisture tolerance ranking for different traits was done for genotypes and based on these ranks, an overall ranking of genotypes was done for each genotype to identify tolerant genotypes for limited moisture conditions. These genotypes subsequently can be used in breeding programme aimed at development of limited moisture tolerance genotypes in fenugreek.

The Table 3 & 4 showed the observation related to stress susceptibility index (SSI), various growth and quality attributes of different genotypes at midterm and terminal growth stage. Stress susceptibility index for seed yield ranged from 0.19 to 2.62. Genotypes B4-22-7-2-1, B5-33-20, B5-5-6-1, B3-77-8-10 and C4-2-14 showed SSI less than one while it was more than one in genotypes A3-31-2-7-2, AFg 3, C4-23-1, A3-31-1-17 and B5-73-11. According to Fischer and Maurer (1978) low stress susceptibility index (S<1) is indicative of higher stress tolerance. Similarly, SSI was calculated for number of pods plant^{-1}, SW:RW, SL:RL and test weight, seed oil%, sapogenin, diosgenin percentage and rank was allotted as per SSI for individual parameter and a overall rank was find out on the basis of mean value and presented in tables 3 and 4.

Perusal of Table 3 & 4 showed that genotype C4-2-14 was top ranked under midterm and terminal growth stage as far as growth attributes are concerned while A3-31-1-17 was top ranked under midterm water stress and genotype B3-77-8-10 was top ranked under terminal stress conditions if evaluated on the basis of seed quality parameters. Interestingly genotype C4-2-14 was stand on 10 and 9 rank when evaluated on the basis of seed quality parameters. Table 5 showed overall rank of different genotypes under MS and TS conditions for growth and seed quality parameters separately. Genotype AFg 3 performed well both under midterm and terminal water stress conditions for quality parameters. However, for growth attributes it performed well under terminal stress conditions only. Results indicated significant GxE interaction effect on genotypes responses for water stress. Since simple and reliable method for screening genotypes for limited moisture are necessary to identify tolerant genotypes, various screening parameters have been assumed by different workers (Pancholi, 1992). Fisher and Maurer (1978) have described a susceptibility index which provides a measure of stress resistance based on minimization of yield loss under stress as compared to

Table 3. Stress susceptibility index (SSI) of different genotypes at midterm stress

	No of Pods		Yield plant^{-1} (g)		SW:RW		SL:RL		Test weight		Over all rank	Oil%		Sapogenin %		Diosgenin %		Over all rank
	SSI	Rank	SSI	Rank	SSI	Rank	SSI	Rank	SSI	Rank		SSI	Rank	SSI	Rank	SSI	Rank	
A3-31-2-7-2	1.37	9.00	2.57	9.00	0.23	3.00	1.72	7.00	-1.73	2.00	6.00	2.02	9.00	0.52	4.00	2.74	8.00	9.00
B4-22-7-2-1	0.29	2.00	-0.14	2.00	1.58	6.00	0.69	3.00	2.53	8.00	4.00	0.15	3.00	2.31	8.00	5.44	10.00	7.00
B5-33-20	0.90	5.00	-0.12	3.00	1.90	9.00	-0.37	1.00	0.06	4.00	5.00	0.93	6.00	2.49	9.00	0.98	6.00	8.00
B5-5-6-1	0.61	4.00	-0.07	4.00	-2.05	1.00	1.00	4.00	2.13	7.00	3.00	0.13	2.00	0.99	7.00	0.71	5.00	4.00
AFG3	1.20	8.00	0.68	5.00	0.81	5.00	0.00	2.00	4.59	10.00	9.00	-0.51	1.00	0.95	6.00	0.68	4.00	2.00
C4-23-1	1.06	6.00	2.39	8.00	2.34	10.00	3.01	8.00	1.20	6.00	10.00	1.44	7.00	0.58	5.00	1.79	7.00	6.00
B3-77-8-10	0.33	3.00	0.80	6.00	0.72	4.00	0.69	3.00	0.12	5.00	2.00	0.56	5.00	-0.02	3.00	3.69	9.00	5.00
C4-2-14	0.19	1.00	-0.29	1.00	-0.61	2.00	0.69	3.00	3.49	9.00	1.00	2.18	10.00	3.00	10.00	0.27	3.00	10.00
A3-31-1-17	2.62	10.00	8.00	10.00	1.62	7.00	1.42	6.00	-2.39	1.00	8.00	0.32	4.00	-0.17	1.00	-0.29	1.00	1.00
B5-73-11	1.11	7.00	1.25	7.00	1.65	8.00	1.06	5.00	-0.24	3.00	7.00	1.94	8.00	-0.12	2.00	0.00	2.00	3.00

Table 4. Stress susceptibility index (SSI) of different genotypes at terminal stress

	No of Pods		Yield plant^{-1} (g)		SW:RW		SL:RL		Test weight		Over all rank	Oil%		Sapogenin %		Diosgenin %		Over all rank
	SSI	Rank	SSI	Rank	SSI	Rank	SSI	Rank	SSI	Rank		SSI	Rank	SSI	Rank	SSI	Rank	
A3-31-2-7-2	0.95	5.00	0.75	3.00	0.14	2.00	0.77	4.00	1.47	10.00	7.00	2.09	8.00	1.67	8.00	-4.86	1.00	7.00
B4-22-7-2-1	0.79	4.00	0.33	1.00	1.23	7.00	1.15	5.00	0.35	1.00	2.00	2.10	9.00	1.40	6.00	-3.24	2.00	8.00
B5-33-20	1.47	9.00	0.67	2.00	0.72	5.00	0.00	1.00	0.95	5.00	4.00	0.98	5.00	1.63	7.00	0.13	4.00	5.00
B5-5-6-1	0.98	7.00	0.86	4.00	-0.09	1.00	1.49	6.00	1.01	6.00	5.00	2.40	10.00	1.79	9.00	0.91	5.00	10.00
AFG3	0.71	3.00	1.01	5.00	0.32	3.00	1.86	8.00	0.88	3.00	3.00	1.25	6.00	-0.67	1.00	1.74	6.00	2.00
C4-23-1	1.50	10.00	1.35	10.00	1.66	9.00	1.86	8.00	0.49	2.00	9.00	2.07	7.00	0.30	3.00	1.85	7.00	6.00
B3-77-8-10	0.97	6.00	1.20	7.00	2.11	10.00	0.38	2.00	0.92	4.00	8.00	-1.96	1.00	0.15	2.00	-0.32	3.00	1.00
C4-2-14	0.45	1.00	1.32	9.00	0.54	4.00	0.38	2.00	1.23	8.00	1.00	0.79	4.00	2.31	10.00	2.45	10.00	9.00
A3-31-1-17	1.41	8.00	1.23	8.00	0.94	6.00	1.58	7.00	1.38	9.00	10.00	-1.46	2.00	0.78	5.00	2.16	8.00	3.00
B5-73-11	0.60	2.00	1.02	6.00	1.51	8.00	0.40	3.00	1.12	7.00	6.00	0.78	3.00	0.77	4.00	2.55	9.00	4.00

Table 1. Overall ranking of genotypes as per growth and quality parameters

Genotypes	Growth parameters		Quality parameters	
	MS	TS	MS	TS
A3-31-2-7-2	6	7	9	7
B4-22-7-2-1	4	2	7	8
B5-33-20	5	4	8	5
B5-5-6-1	3	5	4	10
AFg 3	9	3	2	2
C4-23-1	10	9	6	6
B3-77-8-10	2	8	5	1
C4-2-14	1	1	10	9
A3-31-1-17	8	10	1	3
B5-73-11	7	6	3	4

optimum condition, rather than on yield level under stress *per se*. Thus using formulae of Fischer and Maurer (1978) an attempt was made to assess the susceptibility index of various genotype used in this study. This stress susceptibility index gives an estimate of relative stress injury because it accounts for variation in yield potential and stress intensity (Bruckner and Frohberg, 1987). According to Fischer and Maurer (1978) low stress susceptibility index (S<1) is synonymous with higher stress tolerance. Guttieri *et al.*(2001) using SSI criterion suggested that SSI more than 1 indicates above-average susceptibility and SSI less than 1 indicates below-average susceptibility to drought stress.

In the present investigation all the selected genotype for each of the traits was ranked for the SSI index values. Any genotype having lower SSI was given a higher rank (*i.e.* better suited for stress environment). The ranks of all the traits were then pooled over all the traits and the overall rank determined. A genotype with the lowest total of rank values was considered best for stress environment.

References

Acharya, S., Srichamroen, A., Basu, S., Ooraikul, B., Basu, T. 2006. Improvement in the nutraceutical properties of fenugreek (*Trigonella foenum-graecum* L.). Songklanakarin *J. Sci. Tech.,* 28:1-9.

Acharya, S.N., Thomas, J.E., Basu, S.K. 2007. Breeding of fenugreek (*Trigonella foenum-graecum* L.): a self-pollinating crop. *Advances in Medicinal Plant Res.* 1, 491- 451.

Alhadi, F.A., Yasseen, B.T., Jabr, M. 1999. Water stress and gibberellic acid effects on growth of fenugreek plants. *Irri. Sci.,* 18:185-190

Ali, Q., Ashraf, M., Anwar, F. 2009. Physico-chemical attributes of seed oil from drought stressed sunflower (*Helianthus annuus* L.) plants. *Grasas Aceites*, 60:475-481

Anonymous, 2015. Annual Report 2015-16, ICAR-National Research Centre on Seed Spices, Ajmer.

Anwar, F., Zafar, S.N., Rashid, U. 2006. Characterization of *Moringa oleifera* seed oil from drought and irrigated regions of Punjab, Pakistan. *Grasas Aceites,* 57**:** 160-168.

Araee, M.M., Norouzi, G., Habibi and Sheikhvatan, M. 2009. Toxicity of *Trigonella foenum graecum* (fenugreek) in bone marrow cell proliferation in rat. *Pak. J. Pharm. Sci.*, 22(2):126-130.

Arivalagan, M., Gangopadhyay, K.K., Kumar, G. 2013. Determination of steroidal saponins and fixed oil content in fenugreek (*Trigonella foenum-graecum*) genotypes*. Indian J. Pharm. Sci.*, 110-113

Bruckner, P.L., Frohberg, R.C., 1987. Stress tolerance and adaptation in spring wheat. *Crop Science,* 27: 31-36.

Carvalho, M.H.C. 2008. Drought stress and reactive oxygen species production, scavenging and signalling. *Plant Signal Behav.,* 3(3): 156–165.

Chhibba, I.M., Kanwa, J.S., Nayyarv, K. 2000. Yield and nutritive values of different varieties of fenugreek (*Trigonella spp.*). *Veg. Sci.,* 27:176–179.

Fischer, R.A., Maurer, R., 1978. Drought resistant in spring wheat cultivars and grain yield response. *Aust. J. Agric. Res.,*14: 742-754.

Flagella, Z., Rotunno, T., Tarantito, E., Caterina, R.D., Caro, A.D. 2002. Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regime. *Eur. J. Agron.,* 17:221-230.

Guttieri, M.J., Starl, J.C., Brien, K., Souza, E. 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. *Crop Science*, 41: 327-335.

Hussein, M.M., Zaki S.S. 2013. Influence of water stress on photosynthetic pigments of some fenugreek varieties. *J. App. Sci. Res.,* 9:5238-5245

Jain, A., Singh, B., Solanki, R.K., Saxena, S.N., Kakani, R.K. 2013. Genetic variability and character association in fenugreek (*Trigonella foenum-graecum* L.). *Int. J. Seed Spices,* 3:22-28

Jakhar, R.K., Yadav, B.L., Choudhary, M.R. 2013. Irrigation water quality and zinc on growth and yield of fenugreek (*Trigonella foenum-graecum* L.). *J. Spices and Aromatic Crops,* 22:170-173

Kumar, V., Yadav, J.S., Singh, J., Yadav, B.D. 2000. Irrigation and phosphorus requirements of fenugreek (*Trigonella foenum-graecum* L.) on light soil. *Indian J. Agric. Sci.,* 70:515-517

Malik, T.P., Tehlan, S.K. 2009. Performance of fenugreek (*Trigonella foenum- graecum*) genotypes for growth and seed yield. *Annals of Hort.,* 2: 237-239.

Mishkinsky, J.S., Goldschmied, A., Joseph, B., Ahronson, Z., Sulman, F.G. 1974. Hypoglycaemic effect of *Trigonella foenum graecum* and *Lupinustermis* (leguminosae) seeds and their major alkaloids in alloxan?diabeticand normal rats. *Arch. Int. Pharmacodyn Ther.,* 210:27?37

Nel, A.A. 2001. Determination of sunflower seed quality for processing, Ph. D Thesis. Dept. of Plant Production and Soil Sciences. University of Pretoria, Pretoria, South Africa, pp. 40-56.

Pancholi, S.R., 1992. Inter genotypic difference in advanced generation of bread wheat for salt tolerance. M.Sc. (Ag.) Thesis, RAU, Campus, Jobner.

Petropoulos, G.A. 2002. Fenugreek -The genus *Trigonella,. 1st ed. Taylor and Francis, London and New York.* Pp1-127.

Raman, A., Verulkar, B.S., Mandal, P.N.,Variar, M., Shukla, D.V., Dwivedi, L.J., Singh, N.B., Singh, N.O., Swain, P., Mall, K.A., Robin, S., Chandrababu, R., Jain, A., Ram, T., Hittalmani, S., Haefele, S., Hans-Peter Piepho and Kumar, A. 2012. Drought yield index to select high yielding rice lines under different drought stress severities. doi: 10.1186/1939-8433-5-31

Rathore, S.S., Saxena, S.N. and Singh, B. 2013. Potential health benefits of major seed spices. *Int. J. Seed Spices,* 3:1-12

Sauvaire, Y., Ribes, G., Baccou, J.C., Loubatieères?Mariani, M.M. 1991. Implication of steroid saponins and sapogenins in the hypocholesterolemic effect of fenugreek. *Lipids* 26:191-7

Saxena, S.N., Kakani, R.K., Sharma, L.K., Agarwal, D., John, S., Sharma Y. 2017. Genetic variation in seed quality and fatty acid composition of fenugreek (*Trigonella foenum-graecum*L.) genotypes grown under limited moisture conditions. *Acta Physiologiae Plantarum*. 39:218. Doi: DOI: 10.1007/s11738-017-2522-6.

Singhal, P.C., Gupta, R.K., Joshi, L.D. 1982. Hypocholesterolemic effect of *Trigonella foenum graecum. Curr. Sci.,* 51:136-7

Spyropoulos, C.G. 1986. Osmoregulation, growth and sucrose accumulation in germinated *Trigonella foenumgraecum* (fenugreek) seeds treated with polyethylene glycol. *Physiologia Plantarum*, 68(1): 129-135.

Taylor, W.G., Zulyniak, H.J., Richards, K.W., Acharya, S.N., Elder, J.L. 2002. Variation in diosgenin levels among 10 accessions of fenugreek seeds produced in Western Canada. *J. Agril. Food Chem.,* 50:5994-5997.

Valette, G., Sauvaire, Y., Baccou, J.C., Ribes, G. 1984. Hypocholesterolaemic effect of fenugreek seeds in dogs. *Atherosclerosis,* 50:105-11.

Vyas, D., Kakani, R.K., Agarwal, D., Dubey, P.N. and Saxena, S. N. 2017. Variability in morpho-physiological parameters of fenugreek genotypes. *Int. J. Seed Spices,* 7(2):1-7

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