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Original Research Paper

Exploring the spectrum of variability and identifying donor genotypes for drought stress tolerance in brinjal (*Solanum melongena* L.)

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ABSTRACT

Brinjal (*Solanum melongena* L.) is a nutritionally and commercially important crop and its productivity is hampered by drought stress. Screening and identification of stage specific donor genotypes possibly will be the strategy to improve the productivity. This study assessed the germination and seedling stage drought stress tolerance of 105 brinjal genotypes with polyethylene glycol (PEG). Two PEG concentrations *viz.*, -2 and -6 bars along with water as control were used as treatments. The correlation and linear regression analysis indicated that total seedling length (TSL) and seedling vigor (SV) had highest correlation to drought stress. Stress tolerant genotypes namely Rayadurga Local, Arka Harshitha, Bethapudi local, Arka Avinash and IIHR-586 and Niranjan Bhata, had high and consistent individual and combined mean membership function value (MMFVC) signifying their higher moisture stress tolerance at seedling stage. Field evaluation of the contrasting genotypes showed that the genotypes with higher MMFVC had lower drought susceptibility index (DSI) indicating higher tolerance to drought stress. The findings from the field experiment are in line with the results of the laboratory study, indicating that genotypes with higher MMFVC values exhibit lower DSI values, and vice versa. This consistent pattern further strengthens the reliability of utilizing MMFVC as a preliminary screening method for identifying genotypes with promising stress tolerance capabilities.

Keywords: Brinjal, germination, low moisture stress, membership function value, polyethylene glycol

INTRODUCTION

Brinjal (*Solanum melongena* L., 2n=24) is an often-cross pollinated solanaceous crop grown in tropical and sub-tropical regions of the world due to its nutritional and medicinal value (Gürbüz et al., 2018). Although, biotic stress has been reported as a major problem for brinjal production, abrupt climatic changes in recent days have resulted in frequent occurrence of abiotic stresses has become a common problem. Systematic effort for understanding the variability in brinjal for drought is not well pursued even with the availability of diverse germplasm (Gobu et al., 2017; Hannachi et al., 2022). Screening and identification of genotypes tolerant to drought from the available germplasm is the preliminary step to carry out plant breeding. Seed germination and seedling establishment stage are the most critical stages in the life cycle of brinjal to drought stress (Sikha et al., 2013). Drought tolerance screening under field conditions is largely dependent on uncertain environmental conditions affecting phenotypic expression of a genotype (Wang et al., 2021). Studying the influence of drought using osmotic solutions in germinal phase is one of the best alternative methods for drought tolerance screening (Steiner et al., 2017).

In order to assess the drought tolerance of crop during seed germination and seedling establishment, large molecular weight osmotic chemicals like polyethylene glycol (PEG) are frequently used (George et al., 2015). Polyethylene glycol with molecular mass of 8,000 $gmol^{-1}$ or more is non-penetrable and non-toxic osmotic substance, that can be used to lower the water potential of the germination medium and it has been used to simulate controlled drought stress for screening genotypes to drought tolerance at earlier growth stage in common bean (Aguilar Benítez et al., 2019), tomato (Aazami et al., 2010), pepper (Demirel et al., 2014), and brinjal (Gobu et al., 2017). There are only scanty reports on variability of brinjal genotypes to drought and its effect on germination and seedling growth. Physiological and biochemical indices related to low moisture stress tolerance can be used as criteria for the screening. However, when more genotypes are used for screening, the process is cumbersome and time-consuming. In this study, a simple and efficient method of identifying brinjal variability for PEG induced drought stress tolerance and validation using field experiment was carried out.

MATERIAL AND METHODS

Seeds of 122 brinjal genotypes including 67 commercial hybrids and varieties, 35 local types and 20 wild varieties were obtained from the brinjal germplasm collection of ICAR-Indian Institute of Horticultural Research, Bengaluru, India.

Polyethylene glycol with molecular weight 8000 g mol^{-1} (PEG-8000, >99.0% purity; Sigma Aldrich, St. Louis, USA) was used for screening. Aqueous solutions of -2 and -6 bars water potential were prepared with 115 g and 191 g of PEG 8000, respectively in 1000 mL of distilled water. Five mL of different concentrations of PEG solution and distilled water was added on every alternate day.

Seeds were surface sterilized with 12% sodium hypochlorite and then rinsed thrice with distilled water. Three replicates consisting 30 seeds from each genotype (10 seeds in each plate) were placed in 90 mm diameter plastic petri dishes with a layer of filter paper. Three treatments comprising of 0, -2 and -6 bars water solution was added to respective petri dishes and incubated under controlled conditions in a growth chamber with 50% relative humidity, 600 µmol m^{-2} s^{-1} light intensity, and an average day/night temperature of 25±1°C for 10 and 18 days for germination and seedling growth, respectively.

Determination of PEG induced moisture stress tolerance during germination and seedling growth

Germination percentage (GP), germination index (GI), germination vigor index (GVI), root length (RL), shoot length (SL) and total seedling length (TSL) were measured at 15 days after incubation (DAI) (Moayedi et al., 2009; Mohammadizad et al., 2013). These parameters were calculated as follows:

(i) Germination per centage (GP)

$$= \left(\frac{\text{Number of seeds germinated}}{\text{Number of seeds incubated}}\right) x\ 100$$

(ii) Germination/Seedling vigor index (GVI) = Seedling length × Germination (%)

(iii) $\text{Germination index (GI)} = \frac{Gn}{n}$

where n = number of days after germination;
Gn = number of grains germinated on n^{th} day;

PEG induced drought stress tolerance evaluation

The stress tolerance index (STI) was calculated using the following formula for all the parameters recorded (Fernandez, 1993).

$$\text{STI (x)} = \frac{Vs}{Vc}$$

where, STI = stress tolerance index for x trait,
Vs = value of x^{th} trait in drought stress treatment
and Vc = value of x^{th} trait in control treatment

Then, the drought tolerance level of each genotype was evaluated by the comprehensive evaluation method using the membership function value (MFV) (Zhong et al., 2019).

$$\text{MFV (x)} = \frac{X - Xmin}{Xmax - Xmin}$$

where, MFV (x) = Membership function value of the x^{th} trait/index of a specific genotype

X = Actual measured value for the STI of x^{th} trait in a specific genotype

Xmax and Xmin = Maximum and minimum values for the STI of x^{th} trait observed across all the genotypes, respectively.

Brinjal genotypes were divided into different drought tolerance levels (Z value = 1.64) as follows:

i. High drought stress tolerant (HST):
   - $X_i \geq \ddot{X} + 1.64SD$
ii. Drought stress tolerant (ST):
   $\ddot{X} + 1.64SD > X_i \geq \ddot{X} + 1SD$
iii. Moderately drought stress tolerant (MST):
   $\ddot{X} + 1SD > X_i \geq \ddot{X} - 1SD$
iv. Drought stress sensitive (SS):
   $\ddot{X} - 1SD > X_i \geq \ddot{X} - 1.64SD$
v. Highly drought sensitive (HSS):
   $\ddot{X} - 1.64SD > X_i$

where, X_i = MMFV value of the i^{th} genotype, $\ddot{X}$ = mean of MMFV values from all the genotypes

SD = standard deviation for MMFV of all the genotypes

Characterization of contrasts under field conditions

A set of 20 accessions representing 10 high and 10 low MMFV-Combined (MMFV)C were selected and grown in field with three replications during August, 2022 to December, 2022 at ICAR-Indian Institute of Horticultural Research, Bengaluru, India. All the selected genotypes were subjected to two soil moisture regimes *viz*., well-watered (WW: 100% FC) and water-limited (WL:60% FC). Moisture stress was imposed at flowering stage and maintained until maturity, and fruits were harvested to measure yield of the contrasting genotypes.

Stability in yield for the genotypes was estimated by various tolerance indices which were derived from the yield difference between stress and control conditions

1. Drought susceptibility index (DSI) = (1– Ys/Yc)/D (Fischer & Maurer, 1978)
2. Geometric mean productivity (GMP) = $\sqrt{(Yc \times Ys)}$ (Fernandez, 1993)
3. Mean productivity (MP) = (Yc + Ys)/2 (Rosielle & Hamblin, 1981)
4. Yield stability index (YSI) = Ys/Yc (Bouslama & Schapaugh Jr, 1984)

where, Ys = absolute yield of the genotype under stress condition

Yc = absolute yield of the genotypes under non-stress condition

D = average yield of all genotypes under stress condition/average yield of all genotypes under non-stress condition

Yc is the yield average of all genotypes under non-stress condition

The screening mediated by PEG-8000 data represents the combined results of these two experiments. The data was with one-way ANOVA and Bonferroni's correction. Treatment means were compared using LSD at a significance level of P = 0.01. The scatter plot and linear fit curve were generated using the STI for individual traits and the mean MFV. The R^2 value was used to indicate the relationship between PEG stress tolerance and different traits. For field data analysis, yield (under stress and control conditions) was subjected to analysis of variance, and the tolerance indices were examined using the general linear model (GLM) procedure of SAS V 9.3 (SAS Institute Inc., 2012). The means of yield and tolerance indices were compared using Fisher's LSD test at a 5% probability level.

RESULTS AND DISCUSSION

Effect of PEG stress on germination and early seedling growth parameters of brinjal genotypes

Initial experiment was aimed to identify the variability for drought tolerance at germination and seedling vigor-associated traits. At -6 bars, the GP varied from 0 to 40%, with only two genotypes KS-224 and CO-2 having a GP of 40%, while, genotypes namely Arka Kusumakar, Purple oblong, Black beauty, SKT-Shri Baigan, Niranjan Bhata, Polur Vanga, Brinjal Bhagyamathi and Prasad Seed had GP of 20% (Table 1).

In contrast to -6 bars, the GP under -2 bars PEG treatment ranged from 0 to 100%. Five genotypes, Pusa Hybrid-6, KS-224, Niranjan Bhata, Prasad seed and Utkal Anushree had 100% GP. Thirty-seven genotypes had GP between 20-80% and 63 genotypes had zero GP (Table S1). The reduced seed germination under higher negative osmotic potential in the current study is linked to lower water imbibition and subsequently reduced hydration for reactivation of metabolic and enzyme activities necessary for seed germination (Srivastava et al., 2021). Several studies have reported that increasing osmotic potential has lowered seed germination of different plant species (Mundada et al., 2020; Reza Yousefi et al., 2020). Two genotypes namely, KS-224 and CO-2 proved to be the most tolerant ones to water stress making a

Table 1 : Mean and range of 105 brinjal genotypes screened for moisture deficit stress under controlled and PEG stressed conditions (-2 bars and -6 bars) at seed germination stage

Trait	GP			RL			SL			R/S			GVI			TSL		
	0	-2 bars	-6 bars	0	-2 bars	-6 bars	0	bars -2	bars -6	0	bars -2	bars -6	0	bars -2	bars -6	0	bars -2	bars -6
Mean	100.00	49.05	24.00	2.77	2.60	1.11	3.08	1.75	0.51	96.95	2.31	2.41	6.76	2.08	0.34	5.85	4.35	1.62
SD	0.00	27.30	8.43	1.30	1.26	1.16	1.29	1.24	0.49	36.63	2.20	2.76	4.53	2.43	0.29	2.41	2.16	1.53
Min.	100.00	20.00	20.00	0.47	0.40	0.27	0.40	0.20	0.27	18.45	0.26	0.73	0.54	0.16	0.08	0.90	0.97	0.57
Max.	100.00	100.00	40.00	5.60	5.10	3.40	6.20	4.53	1.90	225.00	13.00	10.00	23.07	12.29	0.96	11.53	8.60	5.30

potential candidate for understanding drought stress tolerance at germination stage.

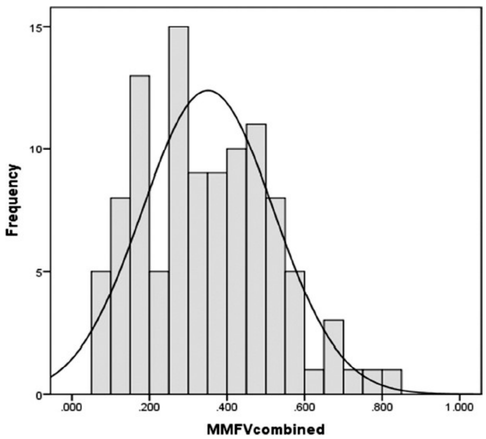
In addition to the GP, GVI and seedling growth were also quantified. At -6 bars, TSL (sum of RL and SL) was highest for the genotypes, Niranjan Bhata, SKT-Shri Baigan, Indian Safed, whereas, at -2 bars, TSL was highest for Niranjan Bhata, Prasad seed and KS-224. The GVI was calculated from the TSL, and was highest in Niranjan Bhata, Poluru Vanga and SKT-Shri Baigan genotypes at -6 bars I (Table S1). The genotype KS-224 with good GP maintained fairly well TSL and GVI. On the contrary, Niranjan Bhata which had good GP with -2 bars and moderate GP at -6 bars recorded good TSL and GVI at both -6 and -2 bars PEG treatment. The observed decrease in growth traits can be explained by the lower moisture availability to the seedlings and subsequent minimal transport of photosynthate from the source to the sink (Butt et al., 2021; Ibrahimova et al., 2021).

The second experiment was focused on identifying the genetic variability for PEG-induced drought stress after the seeds were germinated. With -2 bars PEG treatment, the RL varied from 0.27 cm to 6.77 cm with an average of 2.65 cm. Five genotypes, Bethapudi local, Utkal Anushree, Arka Harshitha, Arka Avinash and Niranjan Bhata had higher RL, compared to the control (Table S2). Consistent with the RL results, Arka Harshitha, Niranjana Bhata, Arka Avinash, Bethapudi Local, Mattu Gulla and Pant Rituraj had higher SL compared to the control (Table S2). Under -6 bars PEG, RL varied from 0.2 cm to 4.57 cm with an average value of 1.2 cm. RL of Pennada Brinjal, Pusa Hybrid-6, Arka Harshitha, Bethapudi Local, Mattu Gulla round, Rayadurga Local has remained the highest (Table S2). The SL of brinjal genotypes varied from 0.2 cm to 5.3 cm with an average value of 2.14 cm. The genotypes Arka Harshitha, Arka Avinash, Bethapudi Local and IIHR-586 genotypes had higher SL and were less affected by stress. Further, the SL of *Solanum gilo*, Polur Local, Pachai green type, *S. acculiatissimum* was highly affected at -6 bars PEG. At -2 bars PEG concentration, TSL varied from 1.17 cm to 12.00 cm with mean of 5.78 cm, whereas, the mean and range of TSL at -6 bars was 9.9 cm and 0.4-3.96 cm, respectively. The TSL was found to be highest for Arka Harshitha, Bathapudi Local, Arka Avinash, IIHR-586, and Niranjan Bhata at both the PEG treatments. The SV results were consistent with RL, SL and TSL results, as evidenced by the higher SV values for Arka Harshita, Niranjan Bhata, Bethapudi local in all the PEG treatments. Higher SV values in these genotypes can be attributed to the faster movement of water molecules during seedling growth. We hypothesize that these genotypes had better accumulation of osmolytes giving protection against low moisture and osmotic stress (Table 2).

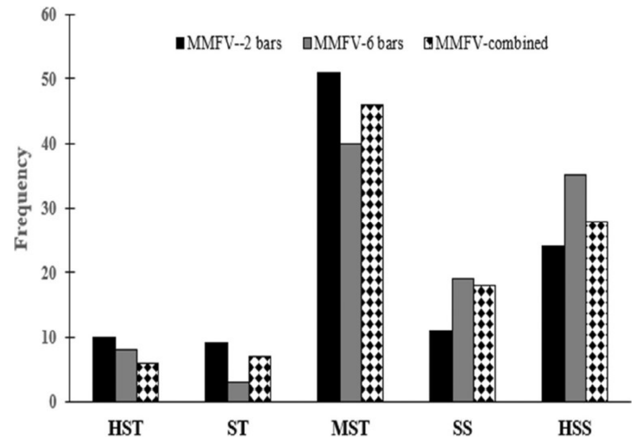
The study of stress tolerance index (STI) variability within the species is suggested as a valuable tool to understand the drought tolerance mechanism (Muscolo et al., 2014). The STI values can be used to evaluate the effect of PEG on the low moisture stress tolerance parameters of the brinjal genotypes. Larger STI values represent a smaller impact, while smaller values indicate greater impacts of stress. To reflect the genetic differences in PEG induced moisture stress tolerance between different genotypes, the STI values were also measured (Table S2). Under -2 and -6 bars, the STI-RL was highest for Arka Harshitha, Bethapudi Local, Arka Avinash, Pusa hybrid-6, Pant Rituraj, Goa Brinjal-3 and Swarna Shakti. The STI-SL was highest for Arka Harshitha, Bethapudi Local, Pant Rituraj, Arka Avinash, Pusa Hybrid-6 and IIHR-586 at both the PEG treatments. STI-SV was highest for the

Table 2 : Mean and range of 105 brinjal genotypes screened for moisture deficit stress under controlled and PEG stressed conditions (-2 bars and -6 bars) at seedling stage

Trait	0		-2 bars		-6 bars	
	Mean ± SD		Mean ± SD		Mean ± SD	
RL	3.46	1.50	2.65	1.50	1.77	1.20
SL	4.38	1.84	3.13	1.18	2.14	1.26
TSL	7.84	2.84	5.78	2.48	3.92	2.19
R/S	0.79	0.28	0.92	0.60	1.16	1.22
SVI	0.78	0.28	0.58	0.24	0.39	0.21



A. Distribution of MMFV-combined



B. Classification of 105 brinjal genotypes according to stress tolerance based on MMFV. HST, high stress tolerant; ST, stress tolerant; MST, moderate stress-tolerant; SS, stress sensitive; HSS: high stress-sensitive

Fig. 1 : Classification of 105 brinjal genotypes based on mean membership function value-Combined (MMFV-C)

genotypes Arka Harshitha, Bethapudi Local, Pant Rituraj, Pusa Hybrid-6 and Arka Avinash and lowest for SM 6-6, Black Star, *S. seaforthium* and Pusa Anupama (Table S2).

Evaluation of PEG induced moisture stress tolerance on germination and growth parameters

To comprehensively identify and evaluate the drought stress tolerance the MFV for each parameter of each genotype, MMFV and MMFVC were calculated. The MMFVC comprehensively reflect the low moisture stress tolerance of a genotype considering each character and each treatment. The larger the MFV of a genotype, the stronger is its stress tolerance.

The MMFV-2 bars ranged from 0.05 to 0.833, MMFV -6 bars ranged from 0.049 to 0.807, and MMFV-combined ranged from 0.065 To 0.807 with an average of 0.351. The frequency distribution of MMFV-Combined is shown in Fig. 1.

Based on moisture stress tolerance indicated by MMFV-Combined, the brinjal genotypes were grouped into five categories (1) six genotypes with highly stress tolerant (HST); (2) seven genotypes were stress tolerant (ST); (3) forty six genotypes were medium stress tolerant (MST); (4) eighteen genotypes were stress sensitive (SS) and (5) twenty eight genotypes were highly stress sensitive (HSS) (Fig. 1B, Table S3). Genotypes Arka Harshitha (0.807), Bethapudi local (0.794), Niranjan Bhata (0.724), Arka Avinash (0.693), IIHR-586 (0.674) had the highest MMFV-Combined; five genotypes, Polur Local (0.065), *S. seaforthianum* (0.071), *S. gilo* (0.078), Pachai green type and *S. acculiatissium* (0.091), had the lowest MMFV-Combined (Table 3). A correlation analysis between MMFV-2 bars and MMFV-6 bars gave $R^2 = 0.65$ ($P<0.001$) indicating two variables have a strong relationship with each other (Fig. 2).

Table 3 : Membership function values (MFVs) and mean membership function (MMFV) of high stress tolerant (HST) and high stress sensitive (HSS) brinjal genotypes at seedling stage

Germplasm	MFV RL		MFV SL		MFV TSL		MFV R/S		MFV-SVI		MMFV	MMFV	Mean	Tolerance
	-2 bars	-6 bars	-2 bars	-6 bars	-2 bars	-6 bars	-2 bars	-6 bars	-2 bars	-6 bars	-2 bars	-6 bars	MFV	
Arka Harshitha	0.85	1.00	1.00	1.00	0.99	1.00	0.21	0.11	0.99	0.93	0.61	0.62	0.81	HST
Bethapudi Local	1.00	0.95	0.85	0.92	1.00	0.93	0.31	0.11	1.00	0.86	0.64	0.59	0.79	HST
Niranja Bhata	0.83	0.73	0.97	0.91	0.96	0.83	0.22	0.08	0.96	0.76	0.61	0.53	0.72	HST
Arka Avinash	0.83	0.97	0.81	0.62	0.88	0.78	0.27	0.18	0.88	0.71	0.56	0.51	0.69	HST
IIIHR-586	0.78	0.97	0.66	0.74	0.76	0.84	0.31	0.15	0.76	0.77	0.51	0.54	0.67	HST
Polur Local	0.00	0.00	0.19	0.21	0.04	0.11	0.00	0.00	0.04	0.06	0.05	0.08	0.07	HSS
Solanum seaforthianum	0.07	0.02	0.14	0.10	0.06	0.06	0.14	0.05	0.06	0.01	0.09	0.05	0.07	HSS
Solanum gilo	0.01	0.00	0.25	0.20	0.08	0.10	0.00	0.00	0.08	0.06	0.09	0.07	0.08	HSS
Pachai Green Type	0.03	0.02	0.21	0.23	0.07	0.13	0.03	0.01	0.07	0.08	0.08	0.09	0.09	HSS
Solanum acculiatissimum	0.07	0.02	0.04	0.00	0.00	0.00	0.34	0.44	0.00	0.00	0.09	0.09	0.09	HSS

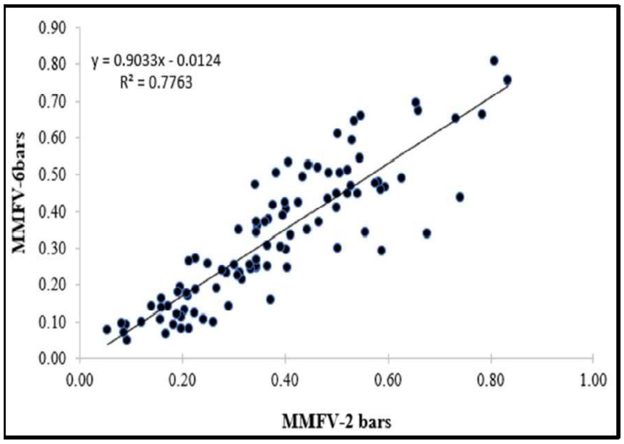


Fig. 2 : Correlation between MMFV -6 bars and -2 bars at seedling stage

Correlation analysis of MFV parameters

Among all the parameters assessed, the correlation between SV and TSL was the highest (r = 0.99) at -6 bars, followed by RL and TSL (r = 0.94) at -2 bars (Table 4). The TSL and SV were highly correlated with MMFV-2 and MMFV-6 treatments. Likewise, TSL and SV were highly correlated with MMFVC, indicating a strong positive correlation between them. Root-to-shoot ratio negatively correlated with TSL and SL at both concentrations of PEG.

To find the most reliable parameters reflecting moisture stress tolerance, a linear model was fitted between STI of each parameter and MMFVC (Fig. 3). The MMFVC had a higher correlation with STIs at -6 bars PEG concentration than that with the -2 bars PEG concentration. Overall, the coefficient of determination was highest for SV (R^2=0.39) at -6 bars and lowest for SL (R^2=0.23) at -2 bar PEG concentration. At -6 bars, the coefficient of determination between the MMFVC and SV was the highest (R^2= 0.39), while, those for RL, SL, and TSL SV were slightly lower, (R^2 = 0.37, R^2 = 0.3.2 and R^2= 0.36). Among the different growth parameters, length of root and shoot is thought to be an essential character for the selection of drought-tolerant genotypes as seedling length contributes significantly to drought resistance (Muscolo et al., 2014). Together, these results indicate that SV and TSL can be used as reliable traits to evaluate the PEG-induced low moisture stress tolerance in brinjal germplasm.

Validation of results in field conditions

Twenty genotypes that were chosen based on MMFVC from a prior laboratory study were grown under field conditions to assess their response to stress. Growth and yield observations were recorded and used to calculate stress tolerance indices (Table 5). The DSI values ranged from 0.23 to 2.02. Among these genotypes, Rayadurga Local (0.234), Mattu Gulla Round (0.408), Pant Rituraj (0.511), IIHR 586 (0.547), and Niranjan Bhata (0.569) displayed the lowest DSI values signifying their higher tolerance to drought stress. The GMP values, which provide a measure of the overall performance of genotypes under

Table 4 : The correlation coefficients between mean membership function values (MFVs) and the parameters of 105 brinjal genotypes

MFVs	PEG	MFV RL			MFV SL			MFV TSL			MFV R/S			MFV SVI			MMFV		
	concentration	0	-2 bars	-6 bars	0	-2 bars	-6 bars	0	-2 bars	-6 bars	0	-2 bars	-6 bars	0	-2 bars	-6 bars	-2 bars	-6 bars	Combined
MFV RL	0	1																	
	-2 bars	0.791	1.000																
	-6 bars	0.718	0.822	1.000															
MFV SL	0	0.438	0.392	0.456	1.000														
	-2 bars	0.548	0.705	0.666	0.456	1.000													
	-6 bars	0.358	0.412	0.586	0.383	0.694	1.000												
MFV TSL	0	0.812	0.672	0.675	0.880	0.585	0.438	1.000											
	-2 bars	0.740	0.941	0.815	0.455	0.903	0.581	0.686	1.000										
	-6 bars	0.598	0.687	0.885	0.470	0.764	0.897	0.621	0.780	1.000									
MFV R/S	0	0.856	0.623	0.501	0.031	0.252	0.123	0.472	0.498	0.345	1.000								
	-2 bars	0.374	0.312	0.195	0.051	-0.311	-0.265	0.231	0.041	-0.046	0.467	1.000							
	-6 bars	0.319	0.262	0.172	0.013	-0.237	-0.464	0.177	0.045	-0.173	0.437	0.730	1.000						
MFV SVI	0	0.812	0.672	0.675	0.880	0.585	0.438	0.500	0.686	0.621	0.472	0.231	0.177	1.000					
	-2 bars	0.740	0.941	0.815	0.455	0.903	0.581	0.686	0.400	0.780	0.498	0.041	0.045	0.686	1.000				
	-6 bars	0.597	0.687	0.885	0.469	0.762	0.896	0.620	0.779	1.000	0.345	-0.045	-0.171	0.620	0.779	1.000			
MMFV	-2 bars	0.791	0.974	0.830	0.454	0.824	0.518	0.712	0.983	0.753	0.571	0.225	0.179	0.712	0.983	0.752	1.000		
	-6 bars	0.680	0.759	0.941	0.480	0.722	0.800	0.671	0.804	0.975	0.449	0.117	0.050	0.671	0.804	0.975	0.806	1.000	
	Combined	0.773	0.911	0.933	0.491	0.813	0.696	0.727	0.939	0.911	0.536	0.179	0.120	0.727	0.939	0.910	0.949	0.952	1.000

RL: root length, SL: shoot length, TSL: total seedling length, R/S: root to shoot ratio, SVI: seedling vigor index, MFV: membership function value, MMFV: mean membership function value

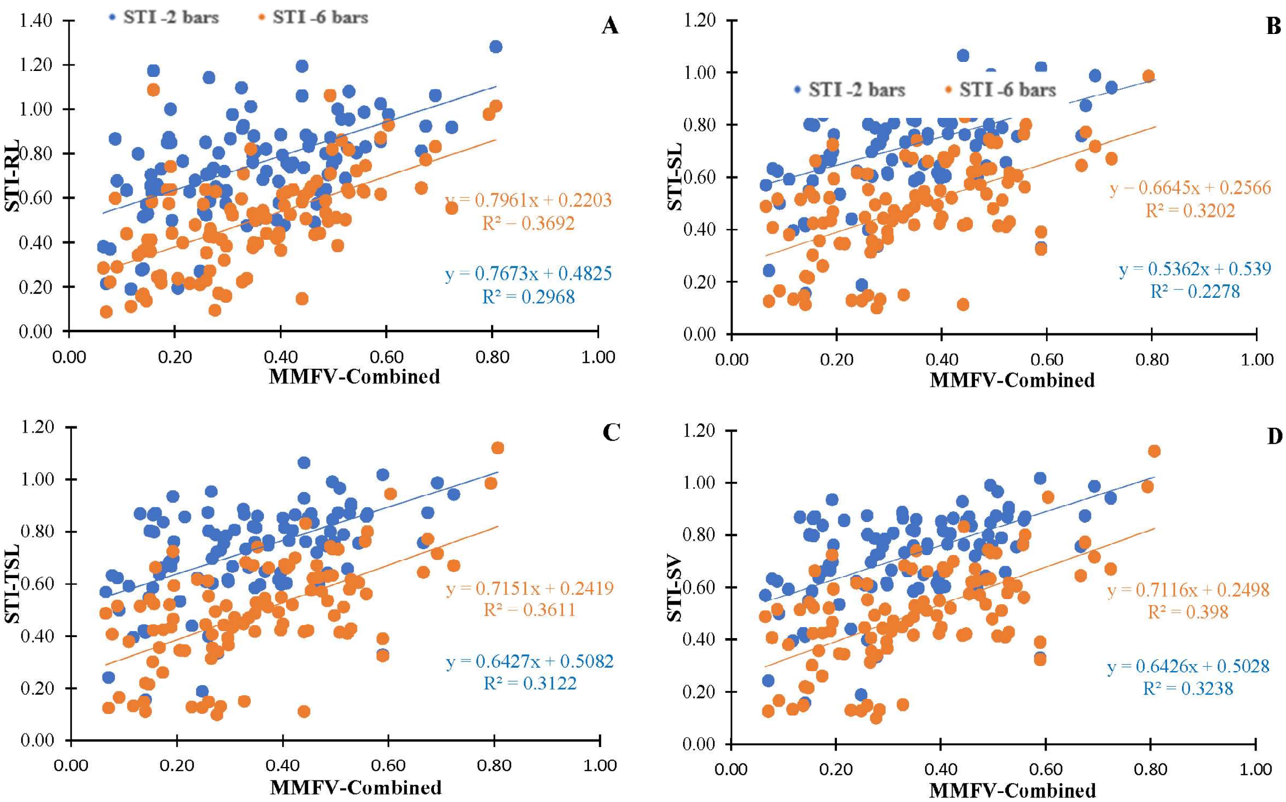


Fig. 3 : A linear correlation analysis between the STI values of each parameter and MMFV-Combined

(A) relationship between the STI of root length (STI-RL) and MMFV-Combined; (B) relationship between the STI of shoot length (STI-SL) and MMFV-Combined; (C) relationship between the STI of the total seedling length (STI-TSL) and MMFV-Combined; (D) relationship between STI of seedling vigor (STI-SV) and MMFV-Combined; R2 (L) is the coefficient of determination

stress conditions, ranged from 0.115 to 35.57. Notably, IIHR-586 exhibited the highest GMP value (35.57), indicating superior productivity even under stressful conditions. Conversely, *Solanum viarum* recorded the lowest GMP value (0.115), indicating a considerable reduction in productivity under stress. The MP values, representing the productivity of genotypes across stress and recovery periods, varied from 36.00 to 0.665. Genotypes IIHR-586 (36.00), Bethapudi Local (26.22), and Niranjan Bhata (24.89) exhibited higher MP values, indicating their ability to maintain productivity despite stress conditions. Furthermore, the YSI values ranged from 0.885 to 0.008, signifying the stability of genotypes under varying stress conditions. Rayadurga Local (0.885), Mattu Gulla Round (0.80), and Pant Rituraj (0.749) showed higher YSI values, indicating their capacity to maintain stable yields across different stress levels. The findings from the field experiment are in line with the results of the laboratory study, indicating that genotypes with higher MMFVC values exhibit lower DSI values, and vice versa (Fig. 4). This consistent pattern further strengthens the reliability of utilizing MMFVC as a preliminary screening method for identifying genotypes with promising stress tolerance capabilities.

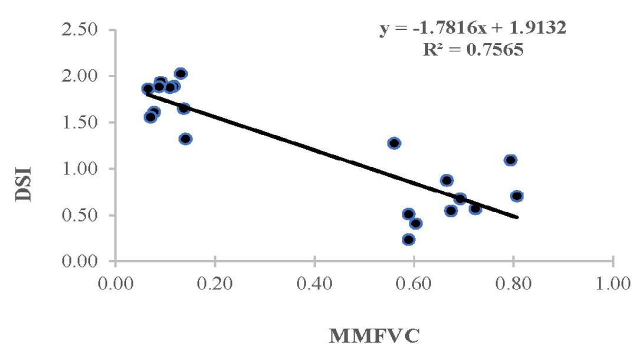


Fig. 4 : Correlation between mean membership function value combined (MMFVC) and drought susceptibility index (DSI) to validate the drought stress contrasting genotypes though polyethylene glycol (PEG) and field experiments. Genotypes in the lower right of the graph encircled with blue circle are with highest MMFVC and lower DSI; at the top left encircled with red are with lowest MMFV and highest DSI

Table 5 : Drought stress tolerance indices derived from yield under stress and control conditions

Classification	Genotype	MMFVC	DSI	GMP	MP	YSI
High MMFV	Arka Harshitha	0.807	0.705	19.218	19.650	0.655
	Bethapudi Local	0.794	1.094	24.403	26.225	0.464
	Niranjan Bhata	0.724	0.569	24.562	24.890	0.721
	Arka Avinash	0.693	0.673	20.151	20.555	0.670
	IIIHR - 586	0.674	0.547	35.571	36.005	0.732
	SKT - Rampriya Baigan	0.666	0.873	12.586	13.080	0.572
	Mattigulla Round	0.604	0.408	18.535	18.650	0.800
	Rayadurga Local	0.589	0.234	17.642	17.675	0.885
	Pant Rituraj	0.589	0.511	21.288	21.510	0.749
	Green long with patches	0.560	1.275	13.872	15.570	0.375
Low MMFV	SM 6-6	0.141	1.323	9.979	11.370	0.352
	Solanum melongena var insanum	0.138	1.649	2.122	2.885	0.192
	Solanum viarum	0.131	2.025	0.115	0.665	0.008
	Pusa Anupama	0.117	1.887	9.479	18.580	0.075
	B-BR-54	0.109	1.874	3.605	6.825	0.082
	Solanum acculiatissimum	0.091	1.937	0.531	1.235	0.051
	Pachai Green Type	0.088	1.881	4.720	9.100	0.078
	Solanum gilo	0.078	1.611	0.697	0.920	0.211
	Solanum seaforthianum	0.071	1.558	1.644	2.090	0.237
	Polur local	0.065	1.862	6.689	12.290	0.088

MMFVC: mean membership function value combined, DSI: drought susceptibility index, GMP: geometric mean productivity, MP: mean productivity, YSI: yield stability index

CONCLUSION

Brinjal genotypes differed for their tolerance to PEG-induced drought stress at seedling stage. Germination and seedling growth were largely inhibited at both concentrations of PEG, however, genotypes such as KS-224, CO-2 and Niranjan Bhata maintained good germination and seedling growth under all the treatments. The present study provided valuable insights into the stress response of twenty genotypes under field conditions. The variation in tolerance indices, including MMFV, DSI, GMP, MP, and YSI, shed light on the diverse responses of different genotypes to drought stress under field conditions. The genotypes Rayadurga Local, Mattu Gulla Round, Pant Rituraj, IIHR-586, Niranjan Bhata, Arka Avinash and Arka Harshitha were identified as drought tolerant with least DSI. These findings could serve as a basis for further research and targeted breeding programs to develop drought-tolerant crop varieties.

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