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Screening of Chilli (*Capsicum annum* L.) Genotypes for Drought Tolerant at Seedling Emergence Stage

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Abstract: Forty seven chilli (*Capsicum annum* L.) genotypes were evaluated for their genetic potential to drought tolerant at germination stage using 12.5% polyethylene (PEG, MW6000). Relative germination energy (RGE), relative germination rate (RGR), relative germination index (RGI), relative vitality index (RVI) and their relative PEG injury rate were computed to identify the most tolerant genotypes on germination stage. Significant differences were observed among the genotypes, treatments and their interactions for evaluated traits suggesting a great amount of variability for drought tolerant in chilli. Based on aggregated score of RGE, RGR, RGI and RVI parameters BD-10906, BD-10912, BD-10911, BD-10916 and BD-10913 were the top five genotypes, whereas BD-10902, RT-20, AM-29, BD-10893 and BD-10930 lowermost five genotypes in the rank of drought tolerant which is an indication of their tolerant and susceptible to drought stress. The lowest relative PEG injury rate was observed in tolerant genotypes, contrary the highest rate was recorded in susceptible genotypes. Dendrogram using Agglomerative Clustering Method grouped the 47 genotypes into four different clusters at the 0.668 co-phenetic correlation coefficient. Drought tolerant chilli genotypes grouped in cluster I, while the susceptible genotypes clustered together in group III and IV and a number of moderate tolerant genotypes gathered in cluster II. Consequently the maximum mean values of tested parameters viz. RGR (91.30), RGE (30.43), RGI (40.58) and RVI (54.10) were observed in clusters I. Positive and significant correlation values were observed between the tolerant indications parameters. RGI showed comparatively strong and positive correlation with all tested parameters. Thus, tolerant and susceptible genotypes will be progressed for further tolerant study in seedling stage.

Keywords: Chilli (*Capsicum annum* L.), Drought, Germination, Tolerance Indices, Relative Injury Rate, Polyethylene Glycol

1. Introduction

Among the different abiotic stresses, drought accounts as one of the leading causes for a decrease in the average yield of more than 50% of many crops in the world [1, 2]. Chilli (*Capsicum* spp.) the family of Solanaceae chromosome number 2n=2x=24 is used as a vegetable, spice, colorant and for some medical applications. It is a valuable spice and also one of the most important cash crops grown in Bangladesh. The acreage, production and yield of chilli in Bangladesh is 182,000ha, 293,000mt and 1.61t/ha, respectively [3]. Drought is one of the main problems for many nations, and the severity of such issue goes big when it comes as obstacle to ensure an optimum agricultural production for a country like Bangladesh. Drought is being considered as the main cause which hampers the estimated agricultural production, here in Bangladesh over the last few decades. In the rabi season (winter), about 1.2 million ha of agricultural land face droughts of different magnitudes [4]. Plants can be affected

by drought at any time of their life, but the critical stages are at germination and seedling growth [5]. This finding was supported by Foolad et al. [6] and Nuruddin et al. [7], who reported that tomato is an important crop under family of Solanaceae of which most cultivars are drought sensitive at all stages of plant development, with seed germination and early seedling growth being the most sensitive stages. Chilli plants have shallow root systems and also very sensitive to drought and water logging. Therefore, there is no doubt how crucial role water plays in the production of the crop. In that situation, tolerant germplasm will play a pivotal role combat against this crucial natural hazardous. Different morphotypes of chilli are available in Bangladesh. Plant Genetic Resources Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI) has been collected and conserved different types of chilli from different parts of Bangladesh. A total of 412 germplasm of chilli were collected in PGRC, BARI up to 2015-2016 under AFACI, IMPGR project from different parts of Bangladesh [8]. Among these collected germplasm, diverse and water stress tolerant chilli germplasm could be used as a source of genetic material for improving the tolerant to drought stress.

Development of stress tolerant varieties has been a major objective of many breeding programs. However, success has been limited by inadequate screening techniques, and lack of genotypes that illustrate apparent differences in response to well-defined environmental stresses. It is important to understand the critical stage for the selection of stress tolerant genotypes. Significant progress has been made in understanding plant growth under drought stress. Drought stress affects developmental stage of the plant. However, damaging effects of this stress was more noted when it coincided with various growth stages such as germination (seedling shoot and root length) and flowering [9, 10]. According to Baloch et al. [11] seedling emergence is one of the most sensitive growth stages that are susceptible to water-deficit. Therefore, seed germination, seedling vigor and coleoptiles' length are prerequisites for successful stand establishment of crop plants. Field experiments related to drought stress have been difficult to handle due to significant environmental or drought interactions with other abiotic stresses [9]. An alternative approach is to induce water stress through polyethylene glycol (PEG) solutions for screening of the germplasm [11-14]. Selection of drought tolerant at the early seedling stage is usually accomplished by inducing chemicals like polyethylene glycol 6000 [15]. Polyethylene glycol molecules are inert, non-ionic, and virtually impermeable to cell membranes and can induce water stress uniformly without causing direct physiological damage [14, 16]. Dodd and Donovan [17] explained that PEG hinders absorption of water by seeds, but penetrable ions reduce potential inside a cell and results in water absorption then starts to germinate. However, no literature is available for chilli under water stress at the germination and early seedling stage.

Previously, Ghebremariam et al. [18] used some parameters like relative growth energy (RGE), relative germination energy (RGE), relative germination energy and relative vitality index (RVI) related to seed germination and seedling vigor for screening of drought tolerant and susceptible tomato inbreed lines at germination and early seedling stage. However, the use of such parameters in screening is still limited. Therefore, in this experiment RGE, RGR, RGI, RVI along with their relative PEG injury rate were used to screening chilli genotypes at germination stage to identify the drought tolerant and susceptible genotypes. Drought tolerant capacity was also ranked based on these parameters.

2. Materials and Methods

The methods of this section were carried out following the protocol of Ghebremariam et al. [18] with some modification to observe the effect of drought on seedling growth parameters and germination indexes of chilli at germination stage. The genotypes which were used in this study were presented in Table 1.

Thirty uniform size, full and without damage seeds were soaked in 55°C water for twelve hours, and then divided into 3 replications of 10 seeds each, and placed on a moistened plastic petri-dish of 9cm diameter. Three replications were treated with osmotic concentration of 12.5% PEG 6000 and the other 3 replications by distilled water as a control. All the treatments were kept in an incubator 25°C and 90% relative humidity. Distilled water and PEG were added regularly when required. Germinated seeds were first counted after 72 hours and then counted every day at the same time for 14 days. A length of five seedlings from every replication was measured after 14 days. Germination rate, germination energy, germination index, vitality index and their relative indexes as well as their relative PEG-injury rate were calculated following Li [19].

$$\text{Germination rate (GR)} = a/b \times 100;\ \text{Germination energy (GE)} = c/b \times 100 \quad (1)$$

$$\text{Germination index (GI)} = \Sigma Gt/\text{day } t;\ \text{Relative PEG injury rate} = (e - d)/e \quad (2)$$

Where,

a = total number of germinated seeds in PEG or distilled water in 14 days.

b = total number of seeds evaluated in one replication.

c = total number of germinated seeds in PEG concentration or distilled water in seven days.

Gt = germinated seeds in day t, t = 1, 2, 3……, 14.

SL = seedling length.

d = GR/GE/GI/VI in PEG.

e = GR/GE/GI/VI of control.

Vitality index was calculated following Lihua et al. [20]:

$$\text{Vitality index (VI)} = GI \times SL \quad (3)$$

And the relative germination indexes were calculated by the following formulas:

$$\text{Relative germination rate (RGR)} = \text{GR in PEG/GR in water} \times 100 \quad (4)$$

$$\text{Relative germination energy (RGE)} = \text{GE in PEG/GE in control} \times 100 \quad (5)$$

$$\text{Relative germination index (RGI)} = \text{GI in PEG/GI in control} \times 100 \quad (6)$$

$$\text{Relative vitality index (RVI)} = \text{VI in PEG/VI in control} \times 100 \quad (7)$$

The experiment was laid out following factorial completely randomized design. Simple correlation among the stress tolerant indices were analyzed statistically using the computer based statistical package STATISTIX 10 and Cluster analysis of genotypes was carried out using Ward's method and Euclidean distance by Statistical package STAR (Version 2.01) [21]. Means were compared by employing least significant difference (LSD) Test at 5% level of probability.

Table 1. *Locations of sites in Bangladesh from which chilli genotypes were collected.*

Sl. no.	Accession/Collector's no.	Location		Sl. no.	Accession/Collector's no.	Location	
		Latitude (N)	Longitude (E)			Latitude (N)	Longitude (E)
1	BD-10878	24°41.516'	89°42.83'	25	BD-10921	22°37.517'	90° 38.062'
2	BD-10879	24°41.516'	89°42.83'	26	BD-10922	22°37.517'	90° 38.062'
3	BD-10884	24°31.511'	89°40.982'	27	BD-10925	22°.11.283'	90° 47.124'
4	BD-10886	24°32.671'	89°40.560'	28	BD-10926	22°.11.283'	90° 47.124'
5	BD-10887	21°58.918'	90°13.60'	29	BD-10929	22°.11.283'	90° 47.124'
6	BD-10888	21°58.918'	90°13.60'	30	BD-10930	22°37.848'	90° 40.251'
7	BD-10889	21°58.918'	90°13.60'	31	BD-10931	22°37.848'	90° 40.251'
8	BD-10891	22°12.889'	90°17.853'	32	BD-10934	22°16.662'	90° 07.331'
9	BD-10893	22°10.413'	90°23.855'	33	BD-10935	22°16.662'	90° 07.331'
10	BD-10900	24°54.490'	89°43.075'	34	BD-10936	22°16.662'	90° 07.331'
11	BD-10901	24°53.026'	89°42.296'	35	BD-10938	23°16.165'	89° 51.434'
12	BD-10902	24°53.026'	89°42.296'	36	BD-10939	25°03.834'	89° 10. 862'
13	BD-10903	24°56.962'	89°52.622'	37	BD-10940	23°99.994'	90° 42. 027'
14	BD-10906	24°56.962'	89°52.622'	38	BD-10941	22°44.170'	90°11.124'
15	BD-10908	24°45.103'	89°49.012'	39	AHM-46	22°39.03'	90°00.51'
16	BD-10909	24°45.918'	89°49.108'	40	AM-29	24°41.925'	89°42. 978'
17	BD-10911	24°45.192'	89°49.415'	41	AMS-12	22°08.008'	90°23.831'
18	BD-10912	24°45.142'	89°49.914'	42	IA-52	23°.30.762'	90°29.715'
19	BD-10913	22°53.037'	90°12.227'	43	BD-10927	22°.11.283'	90° 47.124'
20	BD-10914	22°53.037'	90°12.227'	44	RT-11	24°56.167'	89°55.892'
21	BD-10916	23°17.618'	89°47.259'	45	RT-13	24°56.167'	89°55.892'
22	BD-10917	22°37.848'	90°40.251'	46	RT-20	24°.50.909'	89°53.465'
23	BD-10918	22°37.848'	90°40.251'	47	RT-22	24°45.312'	89°49.112'
24	BD-10920	22°37.517'	90°38.062'	-	-	-	

3. Results

Forty seven diverse chilli genotypes based on their previous morphological and molecular characteristics were screened using PEG to study their response to drought tolerant at germination stage. PEG induced drought caused significant in root and shoot (Figure 1, showing only two best and two worst genotypes) where, BD-10906 and BD-10912 showed the best performance while BD-10902 and RT-20 inferior performance.

The Analysis of variance (ANOVA) revealed highly significant differences among the genotypes for RGE, RGR, RGI, and RVI values (Table 2). Therefore, the selection of genotypes for drought tolerant variety development would be meaningful at seedling emergence stage.

Table 2. *Results of ANOVA analysis of variance for relative germination: energy (RGE), rate (RGR), index (RGI) and relative vitality index (RGI).*

		Sum of squares	df	Mean square	F	P
RGE	Between groups	67709.0	46	1471.93	87.47	≤ 0.001
	Within groups	1581.90	94	16.83		
	Total	69290.80	140			
RGR	Between groups	36196.2	46	786.874	39.31	≤ 0.001
	Within groups	1881.5	94	20.016		
	Total	38077.7	140			

		Sum of squares	df	Mean square	F	P
RGI	Between groups	42907.0	46	932.761	43.18	≤ 0.001
	Within groups	2030.7	94	21.603		
	Total	44937.7	140			
RVI	Between groups	26644.4	46	579.227	33.24	≤ 0.001
	Within groups	1638.0	94	17.426		
	Total	28282.5	140			

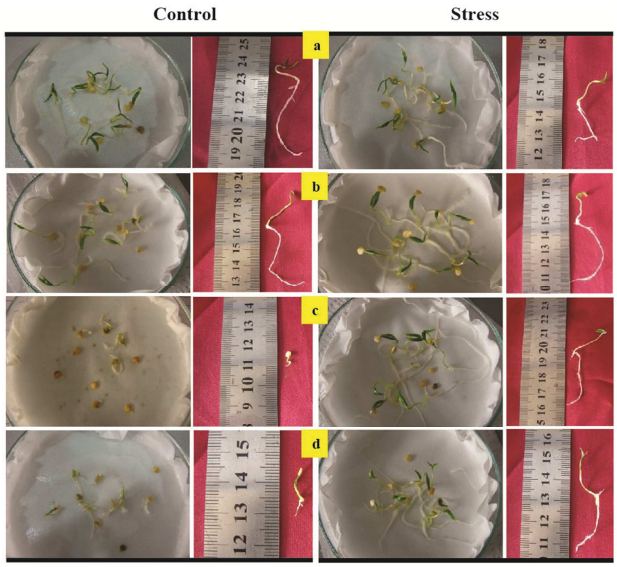

Figure 1. *Photos of seedlings obtained by seed germination on 12.5% PEG6000 and on water of drought tolerant BD-10906 (1a), BD-10912 (1b) and drought sensitive BD-10902 (1c), RT-20 (1d) chilli genotypes.*

3.1. Relative Germination Energy (RGE)

The relative germination energy among the 47 chilli genotypes was significantly affected by 12.5% PEG. As a result, significant variation was observed among the genotypes for RGE (Figure 2a). The highest RGE values of 99.57, 99.47, 94.40, 91.43 and 87.32 were observed in the genotypes BD-10906, BD-10912, IA-52, BD-10908 and BD-10911, respectively. On the other hand, lower RGE values of 16.56, 27.62, 28.45, 28.50 and 28.56 percent were obtained in RT-20, BD-10920, BD-10918, BD-10891, and BD-10903, respectively.

3.2. Relative Germination Rate (RGR)

There was a significant difference among the genotypes in RGR (Figure 2b). Among the genotypes, BD-10906, BD-10908, BD-10911, BD-10912 and BD-10913 had higher RGR with 99.48, 99.42, 99.38, 99.35 and 98.90 percent, respectively while, the lowest values were recorded in RT-20 (30.50) which was followed by those in AM-29 (40.03), BD-10902 (50.10), AHM-46 (50.37) and BD-10889 (55.48).

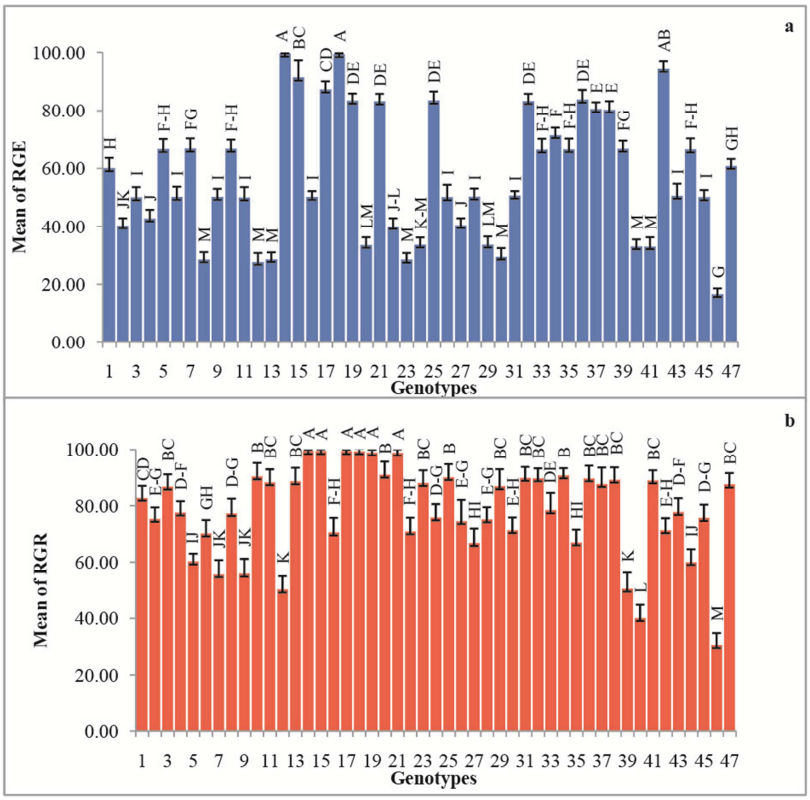

Figure 2. *Relative germination energy- RGE (2a) and rate-RGR (2b) expressed in [%] of the ratios of seeds of chilli genotypes germination energy/rate in PEG and in water.*

3.3. Relative Germination Index (RGI)

Significant variation was also observed among the genotypes under drought for RGI (Figure 3a). Five top most RGI were obtained from BD-10906 (98.38), BD-10912 (98.00), BD-10913 (92.89), BD-10911 (92.28) and BD-10929 (89.45). On the other hand, the genotypes RT-20, BD-10902, AM-29, BD-10930, and BD-10920 had the lowest RGI values of 29.02, 34.99, 40.01, 45.88 and 46.52, respectively.

3.4. Relative Vitality Index (RVI)

Significant difference was noticed among the genotypes in respect of the relative value of vitality index (Figure 3b). The higher top five RVI was found in BD-10887, BD-10912, BD-10906, BD-10934 and BD-10929 with their values 57.01, 56.90, 56.83, 56.39 and 55.06, respectively while, lower five RVI values, 15.28, 15.52, 16.16, 16.55, 16.61 were obtained in BD-10902, RT-20, BD-10893, BD-10917 and BD-10889.

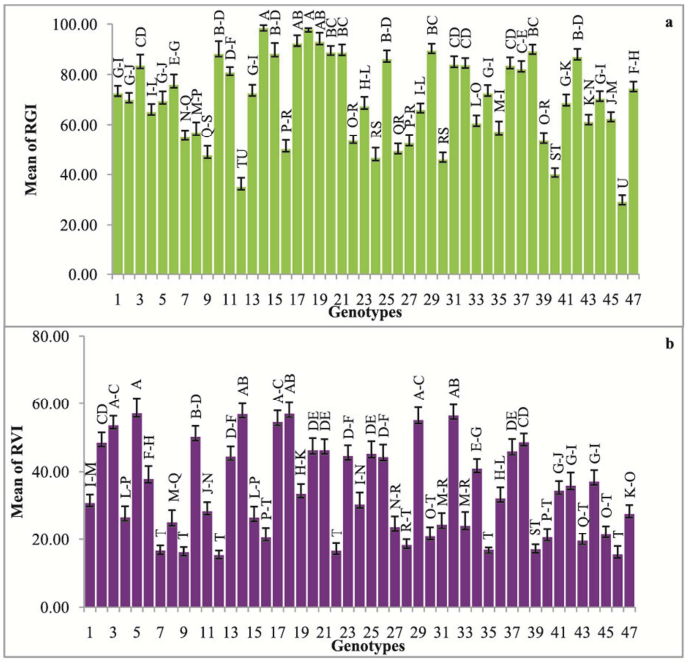

Figure 3. *Relative germination index- RGI (3a) and vitality index- RVI (3b) expressed in [%] of the ratios of seeds of chilli varieties germination index/vitality index in PEG and in water.*

3.5. PEG Injury Rate

It is important that the genotypes showing higher RGR, RGR, RGI and RVI had lower PEG induced injury (Figure 4). Genotypes like RT-20, BD-10920, BD-10918, BD-10891 and BD-10903 recorded higher PEG induced injury values of 0.83, 0.72, 0.72, 0.72 and 0.71, respectively, for germination energy (GE). On the other hand, higher PEG injury rate for germination rate (GR) was 0.70, 0.60, 0.50, 0.50 and 0.55 in RT-20, AM-29, BD-10902, AHM-46 and BD-10889, respectively while higher PEG induced injury in germination index (GI) was 0.71, 0.65, 0.60, 0.54 and 0.54 in RT-20, BD-10902, AM-29, BD-10930, and BD-10920, respectively. The injury rate in vitality index (VI) was 0.85, 0.85, 0.84, 0.83, 0.83 was observed in BD-10902, RT-20, BD-10893, BD-10917 and BD-10889, respectively. It was noticeable that these genotypes had higher RGE, RGR, RGI and RVI values (Figure 2a-b, 3a-b).

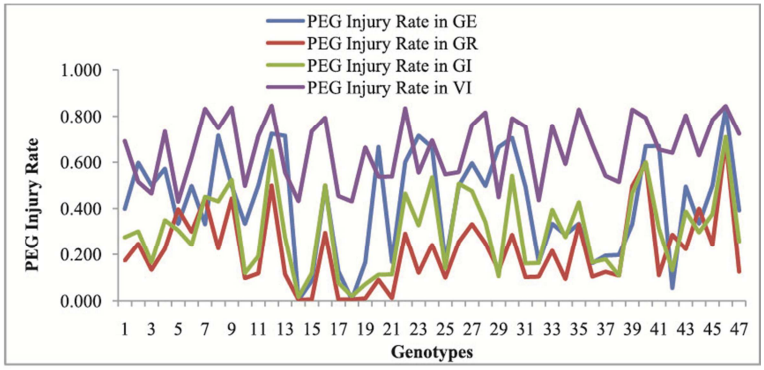

Figure 4. *PEG induced injury for germination energy (GE), germination rate (GR), germination index (GI) and vitality index (VI) of chilli genotypes.*

3.6. Ranking and Grouping of Genotypes Through Multivariate (Cluster) Analysis

The 47 genotypes were ranked according to the aggregated score of RGE, RGR, RGI and RVI parameters. The rank of each genotype is shown in Table 3. BD-10906, BD-10912, BD-10911, BD-10916 and BD-10913 were the top five genotypes, whereas RT-20, BD-10902, AM-29, BD-10893 and BD-10930 lowermost five genotypes in the rank which is an indication of their tolerant and susceptible to water stress. Relative values of GE, GR, GI and VI were used to for cluster analysis using Ward's methods and interval squared Euclidean distance subsequent discriminate analysis for confirming the number of clusters grouped the 47 genotypes into four different clusters with 0.668 phenotypic correlation coefficient.

Table 3. *Ranking of drought tolerant of chili genotypes computed on bases of average values of relative germination: energy (RGE), rate (RGR), index (RGI) and relative vitality index (RGI).*

Sl. no.	Genotypes	Rank	Sl. no.	Genotypes	Rank	Sl. no.	Genotypes	Rank
1	BD-10878	21	17	BD-10911	03	33	BD-10935	29
2	BD-10879	24	18	BD-10912	02	34	BD-10936	13
3	BD-10884	17	19	BD-10913	05	35	BD-10938	35
4	BD-10886	30	20	BD-10914	14	36	BD-10939	11
5	BD-10887	19	21	BD-10916	04	37	BD-10940	12
6	BD-10888	25	22	BD-10917	42	38	BD-10941	07
7	BD-10889	37	23	BD-10918	28	39	AHM-46	39
8	BD-10891	38	24	BD-10920	36	40	AM-29	45
9	BD-10893	44	25	BD-10921	09	41	AMS-12	27
10	BD-10900	08	26	BD-10922	31	42	IA-52	16
11	BD-10901	22	27	BD-10925	41	43	BD-10927	32
12	BD-10902	46	28	BD-10926	33	45	RT-11	26
13	BD-10903	23	29	BD-10929	15	46	RT-13	34
14	BD-10906	01	30	BD-10930	43	48	RT-20	47
15	BD-10908	10	31	BD-10931	18	49	RT-22	20
16	BD-10909	40	32	BD-10934	06	-	-	-

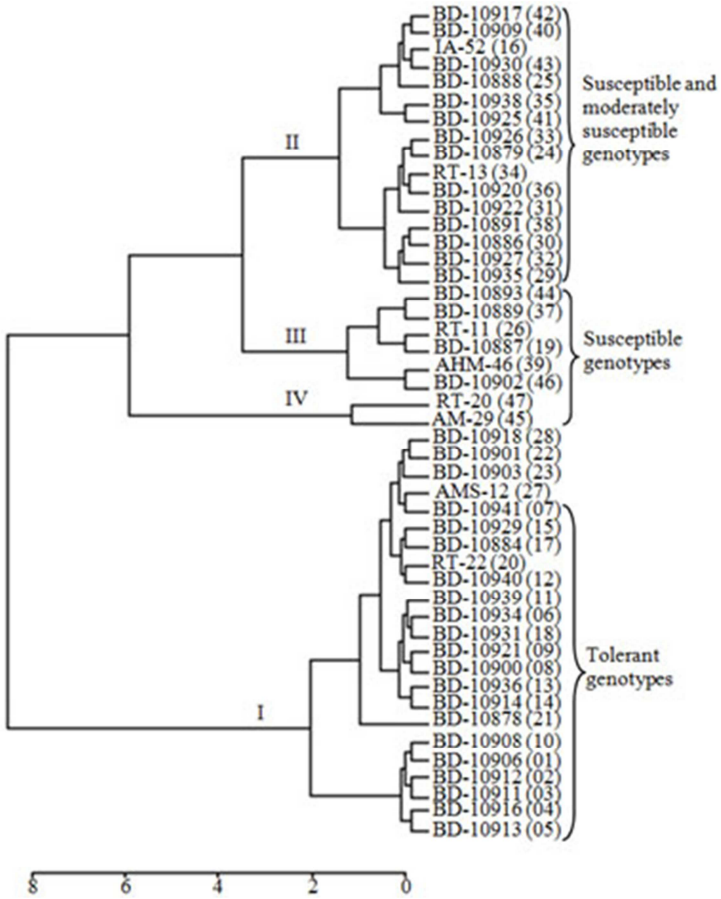

Figure 5. *Dendrogram using Agglomerative Clustering method, summarizing the data on differentiation between 47 chilli genotypes according to the performance of drought stress tolerant parameters at germination stage; Data in parenthesis was expressed the ranking score.*

As it is clearly presented in Figure 5, the first cluster included 23 genotypes [BD-10878 (21), BD-10884 (17), BD-10900 (08), BD-10901 (22), BD-10903 (23), BD-10906 (01), BD-10908 (10), BD-10911 (03), BD-10912 (02), BD-10913 (05), BD-10914 (14), BD-10916 (04), BD-10918 (28) BD-10921 (09), BD-10929 (15), BD-10931 18), BD-10934 (06), BD-10936 (13), BD-10939 (11), BD-10940 (12), BD-10941 (07), AMS-12 (27), RT-22 (20)]. The second cluster comprised 16 genotypes [BD-10879 (24), BD-10886 (30), BD10888 (25), BD-10891 (38), BD-10909 (40), BD-10917 (42), BD-10920 (36), BD-10922 (31), BD-10925 (41), BD-10926 (33), BD-10930 (43), BD-10935 (29), BD-10938 (35), IA-52 (16), BD-10927 (32), RT-13 (34)], the third cluster involved six genotypes [BD-10887 (19), BD-10889 (37), BD-10893 (44), BD-10902 (46), AHM-46 (39), RT-11 (26)] while the genotypes AM-29 (45) and RT-20 (47) formed the fourth cluster.

Multivariate analysis and ranking score based on RGE, RGR, RGI and RVI parameters was used to make the comparison more meaningful towards identifying genotypes or groups tolerant to drought stress. Mean values and standard deviation for relative values of four drought tolerant parameters in four cluster groups are presented in Table 4. It was observed that the maximum values of tested parameters viz. RGR (91.30), RGE (30.43), RGI (40.58) and RVI (54.10) were recorded in cluster I, which was followed by cluster II with all parameters. However, lower values of RGR (35.27), RGE (11.76), RGI (15.67) and RVI (20.90) were obtained from cluster IV, whereas cluster II and III showed medium values of the parameters.

Table 4. *Mean ± standard deviation for four clusters based on four drought tolerant parameters.*

Parameters	Cluster I	Cluster II	Cluster III	Cluster IV
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
RGE	30.43 ± 1.70	24.48 ± 1.26	18.44 ± 1.48	11.76 ± 2.25
RGR	91.30 ± 5.10	73.44 ± 3.78	55.33 ± 4.44	35.27 ± 6.74
RGI	40.58 ±2.27	32.64 ± 1.68	24.59 ± 1.97	15.67 ± 3.00
RVI	54.10 ± 3.02	43.52 ± 2.24	32.79 ± 2.63	20.90 ± 3.99

3.7. Correlations Among Tolerant Indication Parameters

Since correlations are important statistical parameters for selection and crop improvement, correlations between the parameters were measured (Table 5). Positive and significant correlation values were observed between the tolerant indications parameters. RGR expressed significantly positive correlation with RGI (r = 0.8176), RVI (r = 0.5992) and RGE (r = 0.4771). Similarly, RGE showed significant and positive correlations with RGI (r = 0.6630) and RVI (r = 0.3970). It was clear that RGI showed comparatively strong and positive correlation with all tested parameters.

Table 5. *Correlation coefficients among the four tolerant indications parameters in chilli genotypes.*

	RGI	RVI	RGE	RGR
RGI	1			
RVI	0.715**	1		
RGE	0.663**	0.397**	1	
RGR	0.818**	0.599**	0.477**	1

4. Discussion

Drought is one of the prevalent environmental stresses that limits the growth and productivity of crops [22-24]. Moreover, unpredictable drought is happening in different parts of the world due to global warming and climate change. Bangladesh is a one of the most vulnerable country is faced worst effect of climate change. Every five years, Bangladesh is affected by the major country-wide droughts. Northwestern regions of Bangladesh are particularly exposed to droughts. Thus, there is crucial need to select genotypes that can endure water stress. Previous studies proved water deficit to affect seed germination and seedling growth negatively [25]. PEG is one of the reliable laboratory experimental materials to determine the susceptibility of a seed for drought at germination stage, applying the optimum amount is crucial to determine the closest potential effect of drought to the seed. In this study, we used 12.5% PEG 6000 as previous study [26].

Four drought indexing parameters of germination stage like RGE, RGR, RGI and RVI studied for determination of tolerant and susceptible genotypes to water scarcity. A considerable variation among the 47 genotypes was observed regarding different drought indexing parameters. Summarized ranking results based on aggregated score of RGE, RGR, RGI and RVI discriminated the chilli genotypes according to their tolerant performance to drought stress. BD-10906, BD-10908, BD-10911, BD-10912 and BD-10913 were the top five genotypes in the rank which is an indication of their tolerant to drought stress. On the other hand, the lowermost five genotypes in the rank such as RT-20, BD-10902, AM-29, BD-10893 and BD-10930 are the indication of their susceptibility to drought stress. Ghebremariam et al. [18] also used these four parameters to evaluate 45 tomatoes inbred lines response to drought in germination stage.

Results exhibited that germination energy (GE) of different chilli genotypes differed significantly due to application of 12.5% PEG. A considerable genotypic variation in germination rate (RGE) in response to PEG induced drought stress was evident (Figure 2a). Results indicated that the genotypes BD-10906, BD-10908 and BD-10911, which were expressed tolerant to drought, had maximum germination under stress condition. It is clearly observed that tolerant genotype showed their potentiality to overcome PEG injury rate. Alternatively, the susceptible genotypes viz. RT-20, BD-10902, AM-29 were adversely

affected by the drought stress, and for this reason lowest value of the germination energy observed in susceptible genotypes (Figure 4). The RGI showed almost similar trend to RGE. Correspondingly, germination rate is adversely affected by drought in susceptible genotypes. Susceptible genotypes exposed to PEG induced drought stress significantly reduced germination rate. As a result, lowest RGR values were observed in the most susceptible genotypes RT-20 (30.50), BD-10902 (40.00) which is not unusual because of maximum reduction in germination rate compare to control or relative PEG injury rate (0.70 and 0.50) occurred in these genotypes (Figure 4). The reduction in germination percentage may be due to the effect of PEG 6000 that decreases the water potential gradient among seeds and their adjacent media and adversely affects seed germination [17]. Diverse genetic differences were found among the genotypes with respect to germination and there was substantial decline in germination due to PEG injury in all chilli genotypes. These findings are in agreement with the outcomes of the studies [10, 18, 27], who found that germination decreases in stress condition than the normal condition. Good germination under water stress is an important parameter for screening genotypes for drought stress. Moreover, the differences among tolerant and susceptible genotypes were also highly significant in respect to RVI under PEG induced drought stress (Figure 3b). Results also indicated that higher values of RVI containing genotypes were assembled in tolerant group whereas the susceptible genotypes were aggregated by the lower values of RVI. Values of RVI depend on germination index (GI) and root-shoot length. Thus, several studies reported that this parameter could be used as useful traits in selection program for drought tolerant [22-24, 28-30]. Root length is an important trait against drought in plant varieties and genotypes with longer root usually show resistance to drought [31]. Drought tolerant in variety is described by slight decrease of root-shoot growth in drought environments. The reduction in root-shoot length may be due to halt in cell division and cell resulted in tuberization ultimately causing decrease in root and shoot length [32, 33]. In the present study, larger decline in root-shoot length reduced the RVI in susceptible genotypes under stress condition (Figure 3b). However, the minimum PEG injury rate regarding root-shoot length was observed in tolerant genotypes (Figure 4). These findings are in accordance with the statement of the researches [18, 34] who reported that minimum reduction of root-shoot length under water stress condition, a phenomenon commonly found for the screening of tolerant genotypes in dry soils.

The results indicated that the relative PEG injury rate was a good parameter which illustrates the effect of PEG or water stress in the germination capacity and vitality index of the genotypes. Significant difference was observed compared to control which was expressed as PEG injury rate in terms of germination response of the genotypes under the same conditions and the equal amount of PEG. This result was similar to those found on tomato research [18] where the 45 genotypes of tomato planted under the same condition had distinct responses to drought stress. The difference observed in this experiment could be due to variation in water stress tolerant of the genotypes which were also supported by relative injury (Figure 4) where drought tolerant genotypes have smaller relative PEG injury rate. Among the genotypes, BD-10906, BD-10908, BD-10911, BD-10912, BD-10913 and BD-10916 have lower relative PEG injury rate. Contrary, genotypes RT-20, AM-29, AHM-46, BD-10902 and BD-10893 recorded higher relative PEG injury rate (Figure 4). These genotypes with higher values RGE, RGR, RGI and RVI had lower PEG injury.

The cluster analysis revealed that the within group genotypes showed closer genetic distance, while between group genotypes are dissimilar with maximum genetic distance (Figure 5, Table 4). In order to show the value of each cluster regarding investigated parameters mean deviation percent of each cluster was calculated from the total mean (Table 4). The cluster which had the highest mean in comparison with the mean of another cluster could be considered appropriate for use in different improvement plans. The first cluster included 23 genotypes which had the highest mean values and top-ranking score in their tested parameters. The second cluster comprised 16 genotypes showed moderate mean values and conveyed comparatively moderate ranking score, while the third and fourth cluster involved eight genotypes which contained lowest mean value and ranking core regarding their tested parameters (Table 4 and Figure 5). As it is clearly shown in Figure 5, drought tolerant chilli genotypes grouped in cluster I while, the susceptible genotypes clustered together in group III and IV. A number of moderate tolerant genotypes gathered in cluster II. Likewise, our findings are also in close conformity with early reports [18] who ranked 45 tomato inbreed lines based on their relative performance of RGE, RGR, RGI and RVI and water stress tolerant inbreed lines were the top five rank, while the least scorer inbreed lines treated as sensitive to limited water.

The correlation values (Table 5) indicated significant and positive correlations between the water stress tolerant parameters suggesting that increase in any one attribute can increase other traits. Among the four parameters RGI showed strong correlation with the other parameters. It means if one reliable attribute is picked in drought stress and used as a selection criterion that will lead to improve other parameters for drought conditions and better genotypes could be selected to cope with stress environments. Our results are in consonance with Baloch et al. 2012 [35] who noted positive correlations among wheat seedling traits under osmotic or water stress conditions.

5. Conclusion

Different drought indexing parameters were studied for 47 chilli genotypes at seedling emergence stage. Considering all the indices, selection based on RGE, RGR, RGI, and RVI values are important for screening chilli genotypes at

seedling emergence stage. According to these selection indices genotypes BD-10906, BD-10912, BD-10911, BD-10916 and BD-10913 appeared as the best droughts tolerant which were originated as the top five ranking. On the other hand, due to bottom ranking RT-20, BD-10902, AM-29, BD-10893 and BD-10930 turned out as the most sensitive to drought stress. For more precision further evaluation under drought stress will conducted at seedling stage. Furthermore, variations among the tolerant and susceptible genotypes will be determined at biochemical and molecular levels.

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