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Screening of Mungbean Genotypes under Polyethylene Glycol (PEG) Induced Drought Stress Condition

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAI, MNKE and MRF designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author MAB supervised the experiment. Author SAS supervised and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Sixteen advance genotypes of mungbeans under 5 different concentrations of Polyethylene Glycol (PEG) were studied to find out the better cultivar against drought stress condition. The experiment results revealed that germination, seedling production and water-related behavior of mungbean genotypes differed significantly under different PEG (drought inducer) concentrations. The mungbean genotype BINA Mung-6 (V_8) is proved as highly tolerant against drought stress condition among all other tested genotypes. The results of the investigation revealed that BINA Mung-6 (V_8) genotype consistently scored the highest value for all parameters except for the root shoot ratio and water retention capacity that was statistically comparable to genotypes BARI Mung-4 (V_2) and BINA Mung-5 (V_7). Consistently poor performance were recorded from IPM-02-03 (V_{16}) genotype which is

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statistically similar as genotypes BMXK1-09015-2 (V_{13}) and BMXK1-09015-6 (V_{10}). The maximum percentage of germination (98.12%), shoot length (139.40 mm), root length (99.07 mm), shoot dry weight (22.32 mg), root dry weight (6.88 mg), relative water content (94.78), water retention capacity (24.98), germination co-efficient (22.27) and vigor index (233.90) were reported from BINA Mung-6 (V_8) at a concentration of 0 percent PEG. The minimum percentage of germination (28.22 percent), shoot length (31.17 mm), root length (16.50 mm), shoot dry weight (2.21 mg), root dry weight (0.97 mg), relative water content (25.55), water retention capacity (3.08), germination co-efficient (6.06) and vigor index (13.45) were reported from IPM-02-03 (V_{16}) mungbean advance lines at 0 percent PEG. Maximum (0.92) root shoot ratio was recorded from both BARI Mung-8 (V_6) and BMX-08011-2 (V_{11}) mungbean genotypes at 20 percent PEG concentration and minimum (0.22) at 0 percent PEG concentration from BARI Mung-5 (V_3) genotype. Maximum water retention capacity (74.45) was recorded at 20 per cent PEG concentration from IPM-02-03 (V_{16}) genotype and minimum (5.22) was at 0 per cent PEG concentration from BINA Mung-6 (V_8) genotype.

Keywords: Vigna radiata L.; genotypes; polyethylene glycol; drought stress.

1. INTRODUCTION

Drought is a leading abiotic factor, which not only limits plant growth and development but also restricts crop productivity [1]. Drought stress phenomenon influences a variety of morphological, physiological, and biochemical processes in crop plants either temporarily or permanently but adverse. A better knowledge of how drought alters physiological activities, biochemical process and gene regulation of plant is important for enhancing agricultural productivity and breeding efforts [2]. Mungean (*Vigna radiata* L.) is highly significant and common pulse crops, a major component of many global crop systems. It is also known as green gram or golden gram cultivated primarily in India and other Asian nations. Due to its high protein content it is highly consumed in sprouts or in dry seed form [3]. It has a fantastic property of fixing the atmospheric nitrogen to soil ranging from 30 to 251 kg / ha [4] by establishing a symbiotic relationship with Rhizobium bacteria that is also beneficial to the successor crop [5]. It thus also increases soil fertility, which supports the cropping patterns. Because of its short growing period (80-90 days) mungbean can also be used as an intercrop or a cover crop between two cereal crops [6]. Mungbean development is continually threatened by the growing zones stressed by drought. Drought issues for mungbean production are worsening along the quick expansion of the world's water-stressed regions, including 3 billion people by the year of 2030 [7]. Mungbean yields depend upon adequate water supply more than any other single environmental factor [8]. One strategy is to apply drought tolerant cultivars to reduce water stress effect on mungbean production. The growth of drought-tolerant varieties is the best feasible means to resolve this phenomenon for mungbean production, crop yield improvement and stability under heavy water stress conditions [9]. Plant species are typically capable of withstanding these stresses have immense economic potential [10]. This encourages researchers to learn more about the tolerance of mungbean drought which requires a thorough screening of the morphological differences lying beneath. Plants and their response to drought are usually monitored by examining specific morphological and physiological parameters, recognized in many studies as possible measures of drought tolerance, seedling growth and water-related behavior [11]. Application of polyethylene glycol (PEG), an osmotically active, non-toxic and non-penetrating polymer, is an effective laboratory simulation of drought stress [12,13]. The osmotic ability of the medium can easily be controlled in these laboratory tests, and many environmental noises associated with field tests can also be avoided [14]. In view of this framework, the present experiment was carried out to test the drought tolerance mungbean genotypes with the following objectives: to screen the drought tolerant mungbean genotypes and to determine the level of tolerance to which the mungbean tolerant genotypes performed better.

2. MATERIALS AND METHODS

2.1 Sampling and Experimental Materials

During the period February-March/2018, the experimental works were done at the Agronomy Laboratory, the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, with a view to the screening of the drought tolerant mungbean genotypes (*Vigna* *radiate* L). The temperatures and relative humidity at the laboratory were recorded every day. The average minimum and maximum temperature was 25.10°C and 28.92°C, and the mean minimum and relative maximum relative humidity were 56% and 72%, respectively. Polyethylene glycol (PEG) ($H(OCH_2CH_2)nOH$) was used inducing drought stress over the mungbean genotypes. The experiment consists of sixteen mungbean genotypes including nine released by Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) and the remaining genotypes were advanced mungbean lines. The list of the tested genotypes is given below: V_1-BARI Mung-3, V_2-BARI Mung-4, V_3-BARI Mung-5, V_4-BARI Mung-6, V_5-BARI Mung-7, V_6-BARI Mung-8, V_7-BINA Mung-5, V_8-BINA Mung-6, V_9-BINA Mung-8, V_{10}-BMXK1-09015-6, V_{11}-BMX-08011-2, V_{12}-BMX-08011-8, V_{13}-BMXK1-09015-2, V_{14}-BMXK1-09012-1, V_{15}-PM-5 and V_{16}-IPM-02-03. Five levels of concentrations of PEG ($H(OCH_2CH_2)nOH$) such as 0%, 5%, 10%, 15%, and 20% were used as an experimental drought inducer. To prepare 0%, 5%, 10%, 15% and 20% PEG solutions, 0 g, 12.50 g, 25.00 g, 37.50 g and 50.00 g, respectively of PEG crystals were dissolved in 250 ml of distilled water. The experiment was carried out with blotter method and 3 replications using Completely Randomized Design (CRD). Seeds were initially treated in petri dishes for surface sterilization with 70% ethanol (CH_3CH_2OH) for 20 mins. To eliminate the ethanol from the seed surface, the sterilized seeds were rinsed 2 minutes with distilled water for 3 times. To regain normal weight, seeds were then dried in room temperature.

2.2 Germination Percentage

Regular commencement of the number of sprouted and germinated seeds were counted. Germination was reported at an interval of 24 hours, and continued until 8 days. The plumule and radicle were considered to be more than 2 mm long as germinated seed. The germination percentage was calculated using following formula [15]:

Germination percentage (%) =
$$\frac{\text{Total Number of germinated seeds}}{\text{Total seed placed for germination}} \times 100$$

2.3 Dry weight of Shoot and Root

The dry shoot and root weight of the 5 seedlings from each Petri dish was finally measured at 8 Days after sowing (DAS). Dry weight was recorded by drying the sample at 70°C in an oven, until a constant weight was reached. The weight then was converted to milligram (mg) [16].

2.4 Root Shoot Ratio

The root shoot ratio was recorded by using the following formula [16]:

$$\text{Root shoot ratio} = \frac{\text{Root dry weight of seedling}}{\text{Shoot dry weight of seedling}}$$

2.5 Relative Water Content (%)

Relative water content was measured using following formula [8]:

Relative water content (RWC) (%) =
$$\frac{\text{Fresh weight} - \text{Dry weight}}{\text{Tugid weight} - \text{Dry weight}} \times 100$$

2.6 Water Retention Capacity (WRC)

Water retention capacity was measured following formula [27]:

$$\text{Water retention capacity (WRC)} = \frac{\text{Turgid weight}}{\text{Dry weight}}$$

2.7 Co-efficient of Germination

Co-efficient of Germination was calculated using the following formula [14]:

Germination Co-efficient (%)=
$$\frac{A1 + A2 + \cdots + Ax}{A1T1 + A2T2 + \cdots + AxTx} \times 100$$

Where,

A= Number of seeds germinated
T= Time corresponding to A
x= Number of days to final count

2.8 Vigor Index

Vigor Index was calculated using following formula [17]:

$$\text{Vigor Index} = \frac{\text{Total germination} \times \text{Seedling length (mm)}}{100}$$

2.9 Statistical Analysis

For statistical analysis, data recorded for various parameters is compiled and tabulated in the proper form. For statistical testing, CRD analysis was performed. The data were analyzed using the technique "Analysis of Variance (ANOVA)" with the help of the computer package program "MSTAT-C" and the mean separation between the treatments was done by the 1% level of probability test Least Significance Differences (LSD) [18].

3. RESULTS

Current study was carried out to screen for drought tolerant ability of mungbean genotypes under drought-stress conditions. Data on germination, seedling production, and water-related behavior were reported to identify potential mungbean genotypes against polyethylene glycol (PEG)-induced drought stress conditions.

3.1 Germination Percentage (%)

Due to different concentrations of PEG solution, the germination percentage of mungbean genotypes was significantly varied. Initially, most mungbean genotypes responded more or less similarly with respect to germination percentage at 0 percent PEG concentration except for some exceptional ones. The germination percentage decreased with the increase of PEG concentration. But there were variations in the magnitude of the reduction among 16 mungbean genotypes. There was a gradual decrease from 0 percent to 10 percent PEG concentration and a rapid decrease in the concentration of drought susceptible mungbean genotypes from 10 percent to 20 percent. On the other hand, the drought-tolerant genotypes showed more tolerance compared to susceptible genotypes and the germination rate decreased from 0 percent to 20 percent PEG concentration. The result showed maximum germination percentage (98.12%) was recorded from BINA Mung-6 which was almost similar with BARI Mung-4, BARI Mung-7, BARI Mung-5, BINA Mung-5, PM-05 and BARI Mung-6 at 0% PEG concentration whereas the minimum per cent germination (28.22%) was recorded from mungbean genotype IPM-02-03. BARI Mung-4, BARI Mung-7 and BINA Mung-6 mungbean genotypes showed consistently better performances at all PEG concentrations compare to that of other drought susceptible mungbean genotypes.

3.2 Shoot Length (mm)

Shoot length of mungbean genotypes were influenced significantly by several PEG concentrations. The shoot length of the mungbean genotype gradually decreased with increasing of PEG concentration up to 10 percent, and a rapid decrease was recorded with increasing concentration of PEG except for some genotypes of drought tolerance. The experimental findings showed maximum shoot length (139.40 mm) was filed from BINA Mung-6 with a concentration of 0 percent PEG, whereas the minimum shoot length (31.17 mm) was ovserved from IPM-02-03 with a concentration of 20 percent PEG. Mungbean genotype BARI Mung-4 and BARI Mung-7 performed similarly with BINA Mung-6 under most of the PEG concentrations but IPM-02-03 poorly performed under all the PEG concentrations. The rest of the mungbean genotypes responded moderate to weak under conditions of drought stress.

3.3 Root Length (mm)

Concentration of PEG significantly affected the root length of the genotypes of mungbean. In BINA Mung-6, BARI Mung-4 and BARI Mung-7 the extent of root length reduction was slower under different levels of drought stress. The root length ranged from 99.07 mm in BINA Mung-6 to 54.64 mm in IPM-02-03 at 0% PEG concentration; 97.83 mm in BINA Mung-6 to 48.18 mm in IPM-02-03 at 5% PEG concentration; 95.38 mm in BINA Mung-6 to 40.59 mm in IPM-02-03 at 10% PEG concentration; 91.70 mm in BINA Mung-6 to 28.31 mm in IPM-02-03 at 15% PEG concentration and finally, 85.78 mm in BINA Mung-6 to 16.50 mm in IPM-02-03 at 20% PEG concentration. Mungbean genotypes BARI Mung-4 and BARI Mung-7 showed similar performances like as BINA Mung-6 at concentrations of 0 per cent to 10 per cent PEG; BARI Mung-4 demonstrated statistically similar with BINA Mung-6 mungbean genotype at concentrations of 15 per cent and 20 per cent PEG. On the other hand, IPM-02-03 showed consistently poor performance against all levels of drought stress, which was statistically equal to BMXK1-09015-6 at 0 per cent to 20 per cent PEG concentrations and intermediate to poor performance of the rest of the genotypes.

3.4 Shoot Dry Weight (mg)

Dry matter is the dried up to a constant weight of the plant materials. Dry matter accumulation could be an important predictor of robust plant growth capable of storing maximum

Table 1. Performance of mungbean genotypes against drought stress condition under different PEG concentrations.

Genotypes	**Polyethylene glycol (PEG) concentrations (mm)**				
	0%	**5%**	**10%**	**15%**	**20%**
Shoot length					
V_1	91.57 hi	85.70 h	78.82 fg	70.44 f-i	55.32 ef
V_2	137.0 ab	135.8 a	133.8 a	126.7 a	117.1 ab
V_3	121.4 cd	118.0 c	111.5 b	97.89 bc	71.63 d
V_4	106.0 e-h	101.4 d-g	95.04 c-e	81.89 d-g	55.35 ef
V_5	133.1 a-c	132.8 ab	128.5 a	120.4 a	109.8 b
V_6	92.60 g-i	88.32 gh	80.71 fg	69.77 g-i	45.77 fg
V_7	114.3 d-f	110.4 c-e	105.1 bc	95.58 bc	71.01 d
V_8	139.4 a	138.8 a	136.0 a	132.0 a	125.4 a
V_9	101.8 f-i	96.63 e-h	90.53 d-f	76.77 e-h	55.56 e
V_{10}	95.47 g-i	90.07 f-h	83.93 e-g	65.42 h-j	44.79 g
V_{11}	117.3 de	113.2 cd	105.8 bc	91.86 b-d	71.32 d
V_{12}	106.1 e-g	102.2 d-f	94.30 c-e	82.09 d-f	64.28 de
V_{13}	92.17 g-i	88.77 f-h	82.07 e-g	64.04 ij	41.89 g
V_{14}	112.2 d-f	108.4 c-e	101.5 b-d	86.12 c-e	62.57 de
V_{15}	123.4 b-d	119.7 bc	112.5 b	102.3 b	85.30 c
V_{16}	90.12 i	84.04 h	76.09 g	56.58 j	31.17 h
LSD $_{(0.01)}$	**14.50**	**13.78**	**13.12**	**12.18**	**9.62**
CV (%)	**5.85**	**5.75**	**5.81**	**6.14**	**6.21**
Root length					
V_1	72.21 f-h	68.53 e-h	64.91 d-f	58.40 ef	47.78 de
V_2	97.23 ab	95.17 a	93.92 a	87.42 ab	81.35 ab
V_3	76.08 e-g	72.56 d-f	67.10 c-e	61.29 c-e	51.43 d
V_4	66.97 gh	62.62 gh	57.42 fg	46.12 gh	37.37 fg
V_5	93.37 a-c	90.71 ab	87.34 a	82.66 b	76.38 b
V_6	85.09 c-e	83.25 bc	77.75 b	69.07 c	58.08 c
V_7	68.48 gh	65.06 f-h	58.70 e-g	50.84 fg	38.31 fg
V_8	99.07 a	97.83 a	95.38 a	91.70 a	85.78 a
V_9	74.56 f-h	70.95 e-g	63.95 d-f	52.10 fg	36.05 f-h
V_{10}	64.84 hi	60.75 h	53.94 g	42.64 h	30.03 h
V_{11}	80.07 d-f	75.86 c-e	68.28 cd	61.06 de	47.28 de

Genotypes	**Polyethylene glycol (PEG) concentrations (mm)**				
	0%	**5%**	**10%**	**15%**	**20%**
V_{12}	79.37 d-f	75.22 c-e	66.03 d-f	53.69 efg	41.92 ef
V_{13}	55.19 ij	50.49 i	41.64 h	30.04 i	19.43 i
V_{14}	69.46 gh	64.83 f-h	58.08 fg	47.77 gh	33.67 gh
V_{15}	87.48 b-d	82.07 b-d	75.51 bc	68.88 cd	60.46 c
V_{16}	54.64 j	48.18 i	40.59 h	28.31 i	16.50 i
LSD $_{(0.01)}$	**9.90**	**9.79**	**8.93**	**7.97**	**6.63**
CV (%)	**5.79**	**6.01**	**5.97**	**6.12**	**6.23**
Shoot dry					
V_1	13.60 c-e	11.85 f-h	9.43 fg	7.88 f-h	4.26 d-f
V_2	22.06 a	21.64 a	20.52 ab	20.08 ab	17.64 a
V_3	20.48 a	18.54 cd	16.31 c	14.43 c	8.74 c
V_4	15.36 bc	13.60 ef	11.20 de	9.43 de	4.01 ef
V_5	21.24 a	20.53 ab	19.08 b	18.59 b	16.4 b
V_6	14.16 cd	12.43 e-g	10.59 d-f	8.24 e-g	3.74 ef
V_7	16.30 b	14.19 e	11.64 d	8.58 ef	4.51 de
V_8	22.32 a	22.21 a	21.36 a	21.03 a	18.51 a
V_9	13.95 cd	11.70 f-h	9.66 e-g	7.47 f-h	3.34 f-h
V_{10}	12.44 d-f	10.69 gh	9.22 fg	7.05 gh	2.49 g-i
V_{11}	13.75 cd	11.40 gh	10.06 d-g	8.07 e-g	3.74 ef
V_{12}	12.70 d-f	11.35 gh	9.65 e-g	7.49 f-h	3.52 e-g
V_{13}	11.69 ef	10.24 h	8.54 g	6.51 h	2.33 hi
V_{14}	20.55 a	16.79 d	15.30 c	10.75 d	5.27 d
V_{15}	20.72 a	18.77 bc	15.63 c	12.95 c	8.03 c
V_{16}	11.48 f	10.20 h	8.363 g	6.38 h	2.21 i
LSD $_{(0.01)}$	**1.99**	**1.99**	**1.72**	**1.52**	**1.05**
CV (%)	**5.42**	**6.02**	**5.97**	**6.20**	**6.93**
Root dry					
V_1	4.10 fg	3.74 ef	3.57 hi	3.15 f	3.95 c
V_2	6.56 a	6.45 a	6.25 ab	5.95 ab	5.41 ab
V_3	4.48 ef	4.25 c-e	3.84 f-h	3.32 ef	2.31 g
V_4	5.48 c	5.32 b	5.04 d	4.50 d	3.33 d
V_5	6.31 ab	6.21 a	5.94 bc	5.54 bc	5.14 b
V_6	5.88 bc	5.63 b	5.42 cd	5.07 c	3.96 c

Genotypes	**Polyethylene glycol (PEG) concentrations (mm)**				
	0%	**5%**	**10%**	**15%**	**20%**
V_7	5.39 cd	5.24 b	4.93 de	4.39 d	3.21 de
V_8	6.88 a	6.76 a	6.62 a	6.38 a	5.81 a
V_9	4.17 fg	3.98 de	3.78 gh	3.34 ef	2.23 g
V_{10}	3.49 h	3.30 fg	3.09 ij	2.56 g	1.47 h
V_{11}	5.59 c	5.35 b	5.01 d	4.48 d	3.43 d
V_{12}	4.51 ef	4.40 cd	4.21 fg	3.73 e	2.84 ef
V_{13}	3.76 gh	3.39 fg	2.93 j	2.22 gh	1.14 hi
V_{14}	4.85 de	4.61 c	4.42 ef	3.75 e	2.76 f
V_{15}	5.62 c	5.42 b	5.28 d	4.52 d	3.60 cd
V_{16}	3.30 h	3.02 g	2.72 j	1.91 h	0.97 i
LSD $_{(0.01)}$	**0.58**	**0.57**	**0.58**	**0.51**	**0.44**
CV (%)	**5.21**	**5.27**	**5.71**	**5.69**	**6.12**
Root shoot ratio					
V_1	0.303 de	0.317 ef	0.377 d-f	0.403 de	0.900 ab
V_2	0.297 ef	0.297 fg	0.307 f-h	0.293 fg	0.307 h
V_3	0.220 h	0.230 i	0.237 h	0.230 g	0.263 h
V_4	0.357 b	0.393 b	0.450 a-c	0.477 c	0.837 bc
V_5	0.297 ef	0.300 fg	0.310 fg	0.297 fg	0.313 h
V_6	0.417 a	0.457 a	0.513 a	0.613 a	0.917 a
V_7	0.327 c	0.370 c	0.423 cd	0.513 bc	0.713 d
V_8	0.307 c-e	0.307 fg	0.313 fg	0.303 f	0.317 h
V_9	0.300 d-f	0.340 d	0.393 c-e	0.447 cd	0.670 d
V_{10}	0.280 fg	0.310 e-g	0.333 e-g	0.360 ef	0.593 e
V_{11}	0.407 a	0.470 a	0.500 ab	0.557 ab	0.920 a
V_{12}	0.353 b	0.387 bc	0.437 b-d	0.497 bc	0.807 c
V_{13}	0.320 cd	0.330 de	0.343 e-g	0.340 ef	0.487 fg
V_{14}	0.240 h	0.273 h	0.287 gh	0.350 ef	0.523 ef
V_{15}	0.273 g	0.290 gh	0.340 e-g	0.350 ef	0.450 g
V_{16}	0.287 e-g	0.297 fg	0.327 e-g	0.300 fg	0.437 g
LSD $_{(0.01)}$	**0.02**	**0.02**	**0.07**	**0.07**	**0.07**
CV (%)	**5.99**	**6.22**	**6.19**	**5.87**	**6.18**

V_1-BARI Mung-3, V_2-BARI Mung-4, V_3-BARI Mung-5, V_4-BARI Mung-6, V_5-BARI Mung-7, V_6-BARI Mung-8, V_7-BINA Mung-5, V_8-BINA Mung-6, V_9-BINA Mung-8, V_{10}-BMXK1-09015-6, V_{11}-BMX-08011-2, V_{12}-BMX-08011-8, V_{13}-BMXK1 -09015-2, V_{14}-BMXK1-09012-1, V_{15}-PM-5 and V_{16}-IPM-02-03

photosynthetic even under stress (Drought Stress) from source to sink. The shoot dry weight of mungbean genotypes was significantly affected by PEG concentrations. BINA Mung-6, BARI Mung-4 and BARI Mung-7 mungbean genotypes showed consistently slower decreases for shoot dry weight with increased drought stress induced by PEG concentrations. The highest dry weight of the shoot was recorded from BINA Mung-6 genotypes followed by BARI Mung-4 and BARI Mung-7 at all PEG concentrations, whereas IPM-02-03, BMXK1-09015-2 and BMX-08011-8 mungbean genotypes explored greater sensitivity to drought stress and provided the lowest dry weight. Therefore, mungbean genotypes BINA Mung-6, BARI Mung-4, and BARI Mung-7 showed promising performance in terms of shoot dry weight against drought stress condition.

3.5 Root Dry Weight (mg)

PEG concentrations proved a significant influence on the dry root weight of mungbean genotypes. In BINA Mung-6, BARI Mung-4, and BARI Mung-7 the magnitude of root dry weight reduction was lower under various levels of drought stress. The root dry weight ranged from 6.88 mg in BINA Mung-6 to 3.30 mg in IPM-02-03 at 0% PEG concentration; 6.76 mg in BINA Mung-6 to 3.02 mg in IPM-02-03 at 5% PEG concentration; 6.62 mg in BINA Mung-6 to 2.72 mg in IPM-02-03 at 10 % PEG concentration; 6.38 mg in BINA Mung-6 to 1.91 mg in IPM-02-03 at 15% PEG concentration and finally, 5.81 mg in BINA Mung-6 to 0.97 mg in IPM-02-03 at 20% PEG concentration. At all PEG concentrations the mungbean genotypes BARI Mung-4 and BARI Mung-7 showed similar statics as to BINA Mung-6. On the other hand, IPM-02-03 showed consistently poor performance against all rates of drought stress that was statistically equal to BMXK1-09015-2 and BMXK1-09015-6 at 0 percent to 20 percent PEG concentrations and moderate to poor performance of the rest of the genotypes.

3.6 Root Shoot Ratio

Root shoot ratio of mungbean genotypes affected greatly by concentrations of PEG. The result of the experiment revealed that, root shoot ratio ranged from 0.417, 0.457, 0.513, 0.613 and 0.917 in BARI Mung-8 to 0.220, 0.230, 0.237, 0.230 and 0.263 in BARI Mung-5 were recorded at 0%, 5%, 10%, 15%, 20% PEG concentrations, respectively. At all PEG concentrations, mungbean genotype V_6 was similar to V_{11} and V_3 was similar to BMXK1-09012-1 at 0 per cent; BMXK1-09012-1 and BARI Mung-4 at 10 per cent; IPM-02-03 and BARI Mung-4 at 15 per cent; and BARI Mung-7 and BARI Mung-4 at 20 per cent PEG concentrations.

3.7 % Relative Water Content (RWC)

Relative water content (RWC) is a perfect indicator of plant hydrological state which denotes the physiological effects of cellular water deficiency and leaf metabolism. Water potential which has the energy status of plant water is useful for water transport in the soil-plant-atmosphere chain. The relative water content of mungbean genotypes under various PEG solutions has been observed with a wide range of statistical differences. The corresponding water content followed the same trend as previous mungbean genotyping parameters. The results of the experiment revealed maximum relative water content (94.78 percent) was found at 0 percent PEG concentration from BINA Mung-6, and the minimum relative water content (25.55 percent) was recorded at 20 percent PEG concentration from IPM-02-03. BINA Mung-6, BARI Mung-4 and BARI Mung-7 performed clearly superior to IPM-02-03, BMXK1-09015-2 and BMXK1-09015-6 where the rest of the genotypes yielded intermediate results at all concentrations of PEG.

3.8 Water Retention Capacity (WRC)

Water retention capacity is the amount of water that is suitable and uptake by the crop plant. The turgid weight and dry weight ratio (TW / DW) shows the water retention capacity of plants calculated by the cell structures. Plants grown under high moisture condition can retain higher amount and this could be attributed to less moisture-deficient degradation of plant tissues. PEG concentrations influenced significantly the water retention capacity of mungbean genotypes. Maximum water retention capacity was ranging from 24.98, 24.32, 23.38, 22.36 and 21.27 in BINA Mung-6 to 11.39, 10.37, 9.12, 6.85 and 3.08 in IPM-02-03 at 0%, 5%, 10%, 15% and 20% PEG concentrations were attained respectively. IPM-02-03, BMXK1-09015-2 and BMXK1-09015-6 demonstrated significant sensitivity to higher concentrations of PEG. BINA Mung-6, BARI Mung-4, and BARI Mung-7 mungbean genotypes therefore performed better in terms of water retention capacity against drought stress conditions. The tolerance genotypes have the capacity absorbing water even in salt stress condition compared to sensitive ones which also gained the most turgid weight, thereby having the maximum capacity to retain water.

3.9 Co-efficient of Germination

The levels of drought stress condition have significant influence on germination co-efficient of different mungbean genotypes. Total mungbean genotypes perform better in terms of germination co-efficient up to 5 percent PEG concentration but with the development of stress the sensitive ones perform low compared to those of tolerant ones. The result of the investigation revealed that, maximum co-efficient of germination ranged from 22.27, 22.10, 21.38, 20.74 and 19.58 in BINA Mung-6 to 17.84, 17.23, 15.13, 11.52 and 6.06 in IPM-02-03 mungbean genotype at 0%, 5%, 10%, 15% and 20% PEG concentrations, respectively were recorded. BINA Mung-6, BARI Mung-4, and BARI Mung-7 mungbean genotypes therefore performed better in terms of germination co-efficient against drought stress conditions. The co-efficient of germination is representative of germination speed and rapid establishment in reduced water potential.

3.10 Vigor Index

Various genotypes of mungbean significantly varied in the vigor index. The rate of reduction of the vigor index was slower up to 10 percent PEG concentration, but there was a drastic reduction for maximum mungbean genotypes with the rise in PEG concentration from 10 percent to 20 per cent. But with the advent of drought stress the tolerant genotypes retained a normal decrease. The result of the study revealed that, maximum vigor index ranged from 233.90, 230.40, 220.50, 205.20 and 186.10 in BINA Mung-6 to 114.80, 99.37, 76.44, 41.02 and 13.45 in IPM-02-03 mungbean genotype at 0%, 5%, 10%, 15% and 20% PEG concentration, respectively were recorded. Therefore, mungbean genotypes BINA Mung-6, BARI Mung-4, and BARI Mung-7 performed better in terms of vigor index against drought stress conditions.

4. DISCUSSION

Drought stress may affect germination rate, but may be responsive to drought stress during various stages of germination and root initiation [19]. Many researchers have used PEG to induce drought in seeds and seedlings to simulate conditions existing in the field under dry soil or drought [20,21]. The cumulative germination of mungbean genotypes varying from 49.17 to 72.15 per cent and the presence of major germination variations in mungbean genotypes suggested that the physiological means of resistance to drought stress differed with the genotypes. These variations in the stresses of drought in the genotypes will help identify genotypes tolerant to drought stress [22]. Shoot length in PEG-treated grass peas was reduced by 30% compared to control peas and decreased by 41% and 57%, respectively compared to controls in peas [23]. Treatment with -0.4 MPa and control the mean plumule length of all mungbean genotypes was 8.95 cm and 1.14 cm respectively. There was a sudden drop in the length of the plumule from 8.95 cm in control to 1.14 cm in -0.4 MPa and further reduction of the water potential to -0.6MPa and -0.8MPa caused complete inhibition of the growth of the plumules in all the genotypes tested for mungbeans [14]. With rising drought severity the root length in millet was reduced [24]. Root length in PEG-treated grass peas was reduced by 30% compared to control peas and decreased by 41% and 57%, respectively, compared to controls in peas [23]. Mean root length of all mungbean genotypes was 8.82 cm, 7.53 cm, 1.92 cm and 0.65 cm for control, -0.4 MPa, -0.6 MPa and -0.8 MPa, respectively. So, it can be concluded that, for mungbean genotypes immune to drought stress, the root length decreased as the drought condition caused by PEG increased [17]. PEG-induced water deficit stress reduced the shoot length and dry weight of genotypes of wheat [25]. Shoot dry weight were decreased in PEG-treated grass pea by 30 percent as compared to untreated pea, whereas 65 percent reduction of shoot dry weight in PEG-treated pea compared to PEG-treated grass pea [23]. A remarkable reduction in dry weight of plumule and radicle in mungbean was caused by decreasing water potential through PEG. The dry weight of the shoots in different mungbean genotypes decreased at -0.4 MPa from 95.51 percent to 90.4 percent [17]. A 5-day treatment with 20% PEG (−0.53 M pa) resulted in a drastic reduction in root weight in grass pea and garden pea seedlings [23]. Root dry weight of drought stress sensitive mungbean genotypes under drought stress condition was drastically reduced but the magnitude of reduction was slower in the case of comparatively drought stress tolerant ones [26].

Root shoot ratio decreased as drought stress level increased. But in our study, mungbean responded variable in terms of root shoot ratio to low moisture condition [15]. Reduction in root shoot ratio under stress is an indicator of stunted root growth, whereas an increase in root shoot ratio implies more root elongation relative to shoots to reach deeper soil foils to absorb water. Studies associated the rise in the root shoot ratio with high roots and shoots ABA level [16]. A decrease in relative water content affected sensitive pea genotypes more than tolerant pea genotypes under drought stress condition. This could be due to a higher potential for surface water extraction under drought stress due to the comparatively tolerant genotypes [27]. Relative water content (RWC) is well associated with stress strength, grass pea has been able to maintain RWC leaf at 78 percent after 7 days of 20 percent PEG treatment, where relative water content in pea leaf has been declined to 62 percent, indicating grass pea has a lower water deficiency than pea [23]. Reduction of leaf WRC in drought sensitive genotypes may result from accumulation of cellulose and hemi-cellulose in cell wall. Under water stress, there is an opposite relationship between WRC and drought resistance index (DRI). A fall in the WRC leaf showed a decrease in cell size. Reducing the size of the cells is a very common anatomical variation found in leaves under water stress condition [28]. Lowest reduction of water in genotypes of soybean namely Shohag and BARI Soybean-6 which indicate their tolerance capability under water stress phenomenon [29]. Faster the establishment potential of the mungbean genotypes, the greater the germination co-efficient. The cumulative co-efficient of germination was quite high in mungbean genotype SML-1141 which was also characterized by a higher level of germination potential [17]. The high co-efficient of germination in the mungbean genotype would indicate a higher level of tolerance to drought which emphasized the use of germination co-efficient in pulses to screen for drought tolerance [30]. The vigor index results showed percent germination was reduced with increasing of water deficiency, but the level of reduction was not same for all mungbean cultivars at moderate to higher water deficit stress than control. In all concentrations the mungbean genotypes differed significantly for the vigor index [25]. A significant decrease in the mean vigor index of all genotypes 192.76, 88.76 and 19.28 respectively in -0.4 MPa, -0.6 MPa and -0.8MPa concentration. In the genotype of SML-1411mungbean the cumulative vigor index was maximum (294.5) [17]. The findings in mungbean were also consistent with those tests [9].

5. CONCLUSION

Ensuring food security and safe food production for over-growing population is a great challenge for farmers. Different barriers like as abiotic stress (especially drought) exerts further challenges to accomplish the task. Screening of drought tolerance capacity of crop could be a viable method to escape the existing problem. From the current study we found, BINA Mung-6 followed by BARI Mung-4 and BINA Mung-5 gave consistently better output under drought stress condition and gradual linear decreases were observed as PEG concentrations increased from 0 percent to 20 percent. From the findings of the experiment, BINA Mung-6, BARI Mung-4 and BINA Mung-5 could be the promising mungbean genotypes to tolerate against drought stress condition. These mungbean genotypes should be demonstrated in the field condition to find out desired tolerant mungbean genotypes against drought stress condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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