Screening of Mungbean Genotypes for Drought Tolerance Using Different Water Potential Levels

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***Abstract*—Drought is one of the limiting factors for better plant performance and higher yield. New variety selection is difficult due to the wide range of plant stress responses with overlapping functions between their components creating complex mechanisms of resistance. One of the pre-requisites for successful breeding for drought tolerance is availability of reliable methods for screening of desirable genotypes. Classical breeding may be complemented with laboratory methods creating models for simulation of water deficiency and drought conditions. Studies were conducted to find out the effect of reduced water potential treatments on germination and five seedling growth related characters viz., plumule length, radicle length, fresh and dry weight of plumule and radicle and vigour index in mungbean genotypes. In laboratory experiments, water deficiency was simulated by polyethylene glycol (PEG) of MW 6000 in the following concentrations *viz.*, -0.4, -0.6 and -0.8 MPa for seed germination. A linear reduction in germination, shoot and root length, and their corresponding fresh and dry weight was observed for the genotypes as the concentration of PEG increased. The level of the negative effect of the osmoticum on developmental processes was genotype and the reduced water potential dependent. Amongst screened mungbean genotypes, genotype SML-837 recorded no germination at -0.8MPa and this would be critical level of water stress for mungbean whereas genotypes with higher germination index SML-1411 and SML-1136 were found to possess higher level of tolerance to drought.**

***Index Terms*—germplasm, PEG-6000, seed germination, *Vigna radiata*, water stress**

I. Introduction

Drought stress is one of the major causes for crop loss worldwide. Drought stress during the crop growth period is one of the major production constraints in pulses. Mungbean (*Vigna radiata* (L) Wilczek) is an important pulse crop of global economic importance and is the best of all pulses on nutritional point of view [1]. Its complete dependence on monsoon rains for moisture in conjunction with rapidly diminishing rainfall is an impediment for normal physiological processes of growth and development [2]. Depending upon the system soil moisture stress occur due to either early cessation of rain, or low rainfall and poor soil moisture and erratic or insufficient irrigation [3].

Occurrence of dry spell of different magnitude during the crop growth period affect number of physiological and metabolic process like germination, growth, photosynthesis, respiration, nutrient metabolism etc, consequently, leading to poor growth and yield [4]. Therefore there is a great need for drought resistant varieties which could withstand limited soil moisture stress and produce better yield. New variety selection is difficult due to the wide range of plant stress responses with overlapping functions between their components creating complex mechanisms of resistance. One of the pre-requisites for successful breeding for drought tolerance is availability of reliable methods for screening of desirable genotypes [5]. Water potential studies enabled the identification of varieties suitable for growing under moisture stress situations. Varieties that are found to germinate under reduced water potential do not usually fail to germinate and establish into seedlings.

Studies on change in water potential, through use of high molecular weight osmotic substances, like polyethylene glycol (PEG), added to the medium for seed germination or plant/cell development can enable the identification of varieties suitable for growing under moisture stress. In the present study attempt has been to screen mungbean varieties for drought tolerance by evaluating their germination and seedling characteristics under laboratory conditions.

II. Experimental

Twenty five genotypes of summer mungbean viz., SML-1003, SML-837, SML-1136, SML-1361, SML-1002, SML-859, SML-1414, SML-1086, SML-1206, SML-843, SML-1427, SML-1412, SML-668, SML-1073, SML-1205, SML-1164, SML-1165, SML-1178, SML-1023, SML-1360, SML-1411, SML-829, SML-1077, SML-1018 and SML-971constituted the material for the present study. Seeds of uniform size were surface sterilized with 0.1% (w/v) HgCl2 for 1-2 minutes and then washed thoroughly with glass distilled water. Germination test was conducted in Petridishes moistened

Manuscript received July 3, 2016; revised November 21, 2016.

doi: 10.18178/joaat.4.2.159-164

with each of five water potential treatments viz. 0.0 (control), -0.4, -0.6 and -0.8MPa of Poly Ethylene Glycol (PEG - 6000). The experiment was conducted in a CRD design with three replications. In each replication, total of 25 surface sterilized seeds were kept for germination in growth chamber at 25 ℃. Taking emergence of 2mm radicle from the seed coat as the criteria for germination, germination counts were recorded on 2, 4, 6 and 8 days after plating and the average germination percentage was computed. Seedling characters of plumule and radicle length were measured on ten randomly selected 8 day old normal seedlings in each replication. Fresh weight of both plumule and radicle were recorded on the last day. The above ten seedling were oven dried for 24 hours and weighed for recording the dry weight of seedlings. Vigour index (VI) was calculated using the following formula [6]; Vigour index = Dry weight of the seedling X Germination percentage Germination Stress Index (GSI) were calculated by using the following formula given by [7] Germination stress index (G.S.I.) (%) = {P.I of stressed seeds / P.I control seeds} x 100 ,Promptness index (P.I) = nd2 (1.00) +nd4 (0.75) +nd6 (0.5) +nd8 (0.25) ,Where n is the number of seeds germinated at day d

III. Results and Discussion

Genotype wise germination in different water potential treatments including control is given in Table I. In the control, each genotype registered cent per cent germination except for the genotypes SML-1023 and SML-1077, the mean germination of all genotypes in the reduced water potential was reduced, the extent of reduction in germination varying with the genotypes in the individual treatments. In the lowest water potential i.e. -0.4MPa, five genotypes viz. SML-837, SML-1361, SML-1002, SML-1360, and SML-1411 registered germination above 90 per cent and the rest of the genotypes recorded germination between 47.5 and 87.0 per cent. In reduced water potentials lower than -0.4MPa, significant differences were observed in the germination of genotypes. In -0.6MPa, the germination varied from 25% (SML-837) - to 61% (SML-1411). It was thus, apparent that germination significantly decreased in highly reduced water potentials or increased moisture stress. As far as the highly reduced water potential i.e. -0.8MPa was detected to impart huge deterimental effect on germination. At -0.8MPa of reduced water potential germination declined further, ranging between 0 (SML-837) to 35.5% (SML-1411). Seven genotypes (SML-1003, SML-1136, SML-1361, SML-1002, SML-859, SML-1141 and SML-1412 registered germination percent less than 20 at -0.8MPa. The cumulative germination that ranged from 49.17% in SML-1023 to 72.15% in SML-1411 and the existence of significant differences for cumulative germination in the genotypes indicated that the physiological means of tolerance to moisture stress varied with the genotypes. Such differences to moisture stress in the genotypes would be helpful in identification of genotypes tolerant to drought. A decline in germination percentage under increasing moisture stress has been reported in mungbean [8] soyabean [9] pea [10].

The plumule and radicle length of individual genotypes in different water potential treatments are given in Table I. The plumule length in different genotypes was found to be significantly different from one another. The mean plumule length of all genotypes measured 8.95cm and 1.14cm in the control -0.4MPa respectively. It could be seen from the above that there was a sudden fall in the length of plumule from 8.95cm in the control to 1.14cm in -0.4MPa and further reduction of water potential to -0.6MPa and -0.8MPa caused total inhibition in plumule growth in all the tested mungbean genotypes. Similar observations were also reported by [11] in mungbean and blackgram. The radicle length in individual genotype was found to be significantly different from one another in the individual treatments. The mean radicle length of all genotypes measured 8.82cm, 7.53cm, 1.92cm and 0.65cm in the control, -0.4MPa, -0.6MPa and -0.8MPa respectively. As in the case of germination and plumule length, reduction in radicle length was noticed in the highly reduced water potential, the extent of reduction being gradual in the successive reduced water potentials. Increased moisture stress reduced the plumule and radicle length and thus, the normal growth and development. In between plumule and radicle length, plumule length was found very much affected by an increased moisture stress in that the plumule was very much retarded in its growth compared with the radicle. Under reduced water potential germination and seedling growth were variously affected, the variation being specific for genotype [12].

The tendency of the highly reduced water potential either to inhibit germination or suppressed the growth and development of seedlings was also noticed for fresh and dry weight of different tested genotypes (Table II). Decreasing water potential by PEG caused a remarkable reduction in fresh and dry weight of plumule and radicle. Significant reduction in seedling growth in terms of length, fresh and dry weight of plumule and radicle among the genotypes might be attributed to their differential response in term of tolerance level to moisture stress. The fresh weight of shoots under control conditions ranged between 213mg (SML-1206) to 346mg (SML-1361). Lowering of water potential to -0.4MPa led to marked reduction in plumule fresh weight ranged between 96.53 (SML-859) and 90.0 (SML-1411) per cent in different genotypes. Under control conditions, the root fresh weight varied between 166mg (SML-1414) and 96mg (SML-1361). Lowering of water potential resulted in significant reduction in fresh weight of roots of seedlings of all the genotypes. At -0.4MPa water potential, the reduction in root fresh weight ranged between 60% (SMl-1411) to 80.95% (SML-829) and the inhibitory effect became more marked with further lowering of water potential to -0.6MPa and -0.8MPa.

TABLE I. GERMINATION PERCENTAGE (G %) PLUMULE LENGTH P (CM) AND RADICAL R (CM) OF MUNGBEAN GENOTYPES UNDER CONTROL AND DIFFERENT LEVELS OF WATER POTENTIAL

Treatments Genotypes	**Control**			**-0.4 MPa**			**-0.6 MPa**			**-0.8 MPa**			**MCG %**
	G %	**P**	**R**	**G %**	**P**	**R**	**G %**	**P**	**R**	**G %**	**P**	**R**	
SML-1003	100	8.2	8.3	65.0	1.2	8.0	57.0	-	1.9	15.5	-	0.5	59.25
SML-837	100	8.2	9.3	92.5	1.0	7.8	25.0	-	2.1	--	-	--	54.25
SML-1136	100	12.0	7.1	85.0	2.0	6.0	40.0	-	1.1	2.5	-	0.3	56.87
SML-1361	100	12.1	10.1	93.0	0.8	5.6	47.0	-	0.7	6.6	-	0.2	61.65
SML-1002	100	5.3	7.1	90.0	0.7	6.9	30.0	-	0.1	10.0	-	0.2	57.50
SML-859	100	6.5	7.6	47.5	0.5	4.1	37.5	-	2.0	15.0	-	0.1	49.75
SML-1414	100	8.9	9.5	65.5	1.2	8.5	50.5	-	3.0	17.0	-	0.8	58.00
SML-1086	100	7.4	7.2	65.5	0.8	6.5	45.5	-	2.2	20.0	-	0.4	57.50
SML-1206	100	12.7	8.2	77.5	2.0	8.1	52.5	-	2.5	22.0	-	0.7	62.75
SML-843	100	7.6	8.1	85.0	0.8	7.6	57.5	-	3.4	22.5	-	0.8	66.00
SML-1427	100	10.0	12.1	87.0	1.2	7.9	47.5	-	2.0	22.5	-	0.7	64.00
SML-1412	100	8.9	11.4	85.0	1.5	7.2	57.5	-	2.7	15.5	-	0.2	64.25
SML-668	100	10.8	10.5	87.0	2.0	7.7	27.5	-	1.7	25.5	-	0.7	59.75
SML-1073	100	8.2	8.9	67.5	1.1	7.7	50.5	-	1.5	25.5	-	1.1	60.50
SML-1205	100	7.9	7.6	81.0	0.9	6.6	47.5	-	0.5	25.5	-	0.6	63.25
SML-1164	100	7.4	8.5	67.5	1.4	7.3	25.5		1.8	25.5	-	1.3	54.25
SML-1115	100	13.6	11	82.0	1.1	8.6	27.5		1.1	27.0		1.3	59.00
SML-1178	100	9.0	7.2	82.0	1.3	8.8	32.0		1.5	30.0		0.5	61.00
SML-1023	75	10	12.0	57.0	1.3	7.6	47.0		0.8	20.0		0.8	49.75
SML-1360	100	8.0	7.1	92.0	1.5	10.3	60.0		3.5	33.0		1.1	71.25
SML-1411	100	10.2	6.9	95.5	1.9	10.7	61.0		3.5	35.5		1.0	72.75
SML-829	100	7.4	8.1	80.5	0.5	7.7	60.0		1.9	31.0		0.5	67.75
SML-1077	95	7.5	7.6	72.5	0.7	4.8	62.0		3.0	32.0		0.6	65.25
SML-1018	100	8.6	10.8	80.0	0.7	7.6	42.0		1.1	27.0		0.4	62.25
SML-971	100	7.4	8.3	82.0	0.5	8.8	37.0		2.4	22.0		1.0	60.25
Mean	98.8	8.95	8.82	78.6	1.14	7.53	45.08		1.92	22.0		0.65	

CD 5% for Germination Percentage = Genotype (G) = 0.3300, Treatment (T) = 0.6600, G X T = 1.420
CD 5% for Plumule Length = Genotype (G) = 0.1043, Treatment (T) = 0.3719, G X T = 0.5174
CD 5% for Radicle Length = Genotype (G) = 0.0142, Treatment (T) = 0.37219, G X T = 0.0509
Data in parentheses indicate percent increase (+) or decrease (-) over control.
MCG= Mean Cumulative Germination

The dry weight of plumule in seedlings of all the tested genotypes ranged between 21mg (SML-859) to 34mg (SML-1086) under normal conditions. The dry weight of shoots decreased from 95.51% to 90.4% in different genotypes at -0.4MPa. Table II shows variation in root dry weight of seedlings of different genotypes under normal and stressed conditions. In controls, the range of root dry weight per seedling varied between 3mg (SML-837) to 8.0mg (SML-1427). At -0.4MPa of water potential the percent reduction in root dry weight varied between 36.66% (SML-1411) to 71.66% (SML-1136) in genotypes. The magnitude of reduction in root dry weight further increased at -0.6MPa and -0.8MPa. Significant reduction in seedling growth in terms of length, fresh and dry weight of plumule and radicle among the genotypes might be attributed to their differential response in term of tolerance level to moisture stress.

The tendency of the highly reduced water potential either to inhibit germination or suppressed the growth and development of seedlings was also noticed for vigour index and germination stress index calculated for different cultivars (Table III). The mean vigour index of all genotypes 602.20 in the control significantly decreased to 192.76, 88.76 and 19.28 in -0.4MPa, -0.6MPa and -0.8MPa respectively. The cumulative vigour index was maximum in SML-1411 (294.5) and also had high cumulative germination as well. The Germination Stress Index (GSI) is indicative of the speed of germination and quick establishment in reduced water potentials. The higher the germination stress index quicker the establishment capacity of the genotype. The cumulative germination stress index was quite high in SML-1141 which was also characterized by a higher level of germination. Many reports indicated that GSI can be utilized as screening criteria for stress tolerance [13]. The high GSI in above genotype would indicate higher level of tolerance to drought. [14] emphasized the use of GSI in screening drought tolerance in pulses.

TABLE II. FRESH AND DRY WEIGHT OF PLUMULE AND RADICLE (MG) OF MUNGBEAN GENOTYPES UNDER CONTROL AND DIFFERENT LEVELS OF WATER POTENTIAL

Treatments Genotypes	Control				-0.4 MPa				-0.6 MPa		-0.8 MPa	
	Plumule		Radicle		Plumule		Radicle		Radicle		Radicle	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
SML-1003	247	25	120	4.5	17	1.9	23	2.4	11	1.5	3.0	--
SML-837	245	29	98	3.0	24	1.3	33	1.4	9.0	1.3	--	--
SML-1136	250	25	118	6.0	23	2.0	39	1.7	14	2.2	2.0	--
SML-1361	346	23	96	6.6	24	1.7	21	1.9	11	1.6	2.0	--
SML-1002	250	31	111	7.0	20	2.7	22	2.5	8	3.3	2.0	--
SML-859	231	21	123	6.0	8.0	1.5	26	2.2	17	2.2	2.0	--
SML-1414	288	28	166	6.0	19	2.5	39	2.0	12	1.6	6.0	1.2
SML-1086	264	34	107	5.3	15	2.7	26	1.6	13	1.7	6.0	1.1
SML-1206	213	30	132	4.9	14	2.4	48	1.9	14	1.3	5.0	--
SML-843	231	28	125	4.0	14	2.1	40	2.1	19	2.1	3.0	1.0
SML-1427	296	31	125	8.0	22	2.3	38	2.6	16	2.4	8.0	1.0
SML-1412	267	31	110	6.5	20	2.3	40	2.9	14	3.3	5.0	1.1
SML-668	250	29	130	6.0	21	2.1	43	2.7	12	2.1	2.0	1.2
SML-1073	280	29	121	6.0	24	1.9	41	2.1	17	1.9	9.0	1.0
SML-1205	260	32	109	5.3	19	2.1	26	2.9	15	1.8	70	1.0
SML-1164	283	27	111	4.0	17	1.7	41	2.4	11	2.2	4	1.1
SML-1115	228	29	103	5.3	19	2.1	31	2.4	10	2.1	6.0	1.1
SML-1178	256	25	110	6.4	20	1.8	32	1.8	14	1.0	3.0	--
SML-1023	267	32	96	5.9	22	2.3	37	3.2	8.0	1.8	3.0	1.0
SML-1360	260	22	102	5.8	21	2.1	40	3.1	23	2.9	11.0	1.6
SML-1411	242	37	120	6.0	22	3.0	48	3.8	22	2.1	10.0	1.4
SML-829	265	33	147	7.1	21	1.8	28	3.3	17	2.3	7.0	1.2
SML-1077	240	31	111	6.1	14	1.8	32	2.1	16	1.4	6.0	1.1
SML-1018	235	27	128	7.0	13	1.7	37	2.6	11	1.4	3.0	1.0
SML-971	259	29	112	6.5	20	2.1	32	3.0	14	1.9	6.0	1.1

CD 5% for Plumule fresh weight = Genotype (G) = 0.16, Treatment (T) = 0.42, G X T = 1.03,
CD 5% for Radicle fresh weight = Genotype (G) = 0.13, Treatment (T) =0.24, G X T = 0.37,
CD 5% for Plumule dry weight = Genotype (G) = 0.14, Treatment (T) = 0.37, G X T = 1.04
CD 5% for Radicle dry weight = Genotype (G) = 0.09, Treatment (T) =0.17, G X T = 0.37

TABLE III. VIGOUR INDEX (VI) AND GERMINATION STRESS INDEX (GSI) OF MUNGBEAN GENOTYPES UNDER CONTROL AND DIFFERENT LEVELS OF WATER POTENTIAL

Treatments Genotypes	Control	-0.4 MPa		-0.6 MPa		-0.8MPa		Cumulative Mean	
	VI	VI	GSI	VI	GSI	VI	GSI	VI	GSI
SML-1003	475	157	54.3	85	21.0	--	8.3	179.5	27.8
SML-837	329	130	26.7	32	19.3	--	--	122.7	8.90
SML-1136	625	146	24.0	88	15.0	--	3.2	214.7	14.0
SML-1361	683	178	36.2	75	23.0	--	6.3	234.0	21.8
SML-1002	731	227	62.0	99	27.5	--	5.1	264.2	31.5
SML-859	621	104	49.2	81	25.0	--	2.3	201.5	25.5
SML-1414	628	132	63.6	80	25.9	20	5.8	215.0	31.7
SML-1086	564	106	65.0	76	31.0	22	6.4	192.0	34.1
SML-1206	520	148	62.5	67	23.5	--	8.7	183.7	31.5
SML-843	428	180	28.3	119	15.0	22	1.8	187.2	15.0
SML-1427	831	228	53.0	102	24.7	22	6.3	290.2	28.0

SML-1412	681	248	56.4	188	30.6	16	4.0	283.2	31.0
SML-668	629	237	60.0	56	22.9	30	0.7	238.0	27.8
SML-1073	629	142	69.3	95	30.4	25	7.5	222.7	36.0
SML-1205	562	237	67.6	84	28.6	25	5.0	227.0	33.7
SML-1164	427	162	62.2	55	27.1	27	3.3	167.7	30.8
SML-1115	559	198	58.3	56	28.2	29	8.5	210.5	31.6
SML-1178	665	149	36.7	32	19.3	--	6.3	211.5	20.7
SML-1023	474	184	44.0	84	25.0	20	5.9	190.6	24.9
SML-1360	602	287	66.2	174	30.0	52	12.1	278.7	36.1
SML-1411	637	364	72.0	128	25.5	49	11.9	294.5	36.4
SML-829	743	255	59.2	118	13.0	37	9.3	285.7	27.1
SML-1077	610	153	63.6	86	25.9	35	11.8	221.1	33.7
SML-1018	727	209	65.0	58	30.0	27	9.4	255.2	35.1
SML-971	679	248	72.5	70	24.5	24	0.7	255.2	32.5
Mean	602.36	192.76	55.11	88.72	24.47	19.28	6.25		

CD 5% for Vigour index = Genotype (G) = 0.85, Treatment (T) = 2.24, G X T = 3.48

CD 5% for Germination Stress Index (GSI) = Genotype (G) = 0.3783, Treatment (T) =0.4204, G X T = 0.8534

IV. Conclusion

Screening of genotypes based on single morphological parameters appears to be limiting due to inconsistency in growth responses of same seedling in response to drought. Screening on the basis of germination percentage, germination stress index and vigour index can be considered as a useful tool to screen drought tolerant genotypes. Amongst screened mungbean genotypes, genotype SML-837 recorded no germination at -0.8MPa and this would be critical level of water stress for mungbean whereas genotypes with higher germination index SML-1411 and SML-1136 were found to possess higher level of tolerance to drought.

Acknowledgement

One of the authors (Rajwinder Kaur) would like to appreciate help and support provided by Department of Plant Breeding and Genetics, PAU, Ludhiana, for allocating field area and research material and also to Department of Botany, PAU, Ludhiana, for providing laboratory facilities.

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