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Study on Physiological Growth Parameters in Semi Drought Tolerant Genotypes of Mungbean (*Vigna radiata L. Wilczek*)

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Abstract: *Fourty four elite drought tolerant genotypes collected from various parts of the country were evaluated for growth traits namely Mean productivity (MP), Rate productivity (RP), Drought susceptibility index (DSI), Drought tolerance index (DTI), Tolerance to drought stress (TDS), Relative water content (RWC), Leaf Area (LA), Leaf area Duration (LAD), Crop Growth rate (CGR), Relative growth rate (RGR), Net assimilation rate (NAR) and Harvest index (HI).Significant differences were observed among the accessions and percentage reduction in growth parameters were deciphered for each of the above growth parameters among the accessions.*

Keywords: *Vigna radiata L. Wilczek., Polyethylene glycol (PEG), water stress, seedling traits.*

INTRODUCTION

Drought have been proved beyond drought that it an intricate trait which is influenced by biometric, bio-physiological, morpho-physiological and biochemical components (Sunil Kumar *et al.*, 2015; Babaeian *et al.*, 2011; Demirevska *et al.*, 2009). It has also been shown that the physiological responses of plants to drought stress is extremely complex and vary with plant species as well as with the degree and time of the exposure to drought (Sunil Kumar *et al.*, 2015, Levitt, 1980; Bennett, 1990; Evans *et al.*, 1990, 1991; Jones 1993; Reynolds, 2002; King, 2011). Plants develop different morphological, physiological and biochemical mechanisms which inhibit or remove the harmful effects of drought stresses (Sullivan and Ross, 1979; Boyer,1982; Larsson and Gorny, 1988; Chaves *et al.*, 2002; Reynolds *et al.*, 1998; Asharaf, 2010). Drought tolerance of a plant species is usually determined by the plant's genes and also by morphological, phonological, physiological, and biochemical traits. The responses of plants to drought stress depend on the species, genotype, plant age, level and duration of drought, and physical parameters of the soil. The degree of drought tolerance allow for a direct or indirect estimation of the various physiological, biochemical or morphological traits of the examined genotypes. Measurements of different physiological processes of plant response to drought provide important information about the reactions of the plant intended to remove or to reduce the harmful effects of water deficit in the soil or plant tissues. Techniques of screening for drought tolerance were devised by selecting genotypes in a field or greenhouse study. Conducting field experiments is necessary for the verification of the drought tolerance estimated on the basis of physiological laboratory tests (Grzesiak, 1990; Richards, 1991; Kpoghomou *et al.*, 1990).

For proper field testing a number of methodological problems must be solved to enable water content in the soil to be controlled by irrigation or by limiting the in flow of water from rainfall. The relations between the plant yield obtained under conditions of drought and that obtained under conditions of optimal soil

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moistening were preferred among the field indices of drought tolerance. Such tests, however, are not accurate enough or too simplified to show important relations between the crop forming processes and soil–water-plant relationship. A more precise quantitative formulation of this relationship can be found in the studies by Fischer and Maurer (1978), Hanson and Nelson (1985), Winter *et al.* (1988), Stanley (1990) and in FAO reports by Doorenbos and Pruit (1977); Doorenbos and Kassam (1986).

The most important laboratory methods suggested for screening for drought tolerance in crop plants were germination in osmotic substances (mannitol, PEG), growth or survival of young seedlings subjected to soil or simulated water stress and high temperature stress (Sullivan and Ross, 1979; Blum and Ebercon, 1981; Martinielio and Lorenzoni, 1985). Yield indexes namely Mean productivity, Rate productivity, Drought susceptibility index, Drought tolerance index and Tolerance to drought stress were also found to be very important for estimating and for identification of drought tolerant genotypes.

MATERIALS AND METHODS

Experimental Site and its Description

The experiment was conducted during January to April, 2016 at the Pot Culture Yard, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai university, Annamalai Nagar (11° 24' 0" N and 79° 44′ 0″ E). The minimum and maximum mean temperatures recorded during the crop period ranged from 19°C to 38°C and the average rainfall recorded was 8.5 mm with an average relative humidity of 75 percent. The experimental pot was filled with potting mixture of garden soil, peat and sand (1:1:1). Air-dried soil substrate was sieved in a 0.25 cm mesh. Soil substrate pH was 7.1 and the percent of organic material was 0.7% for the determination of root length and number of root system components and seedlings traits. Recommended fertilizer dose was applied and need based protection measures were adopted for raising a healthy crop.

Experimental Design

The experimental area was covered with a temporary setup using PVC (polyvinyl chloride) film (of about 0.15 mm thickness and 85% of transmittance) to avoid rainfall. The pots were arranged in 44 rows and three columns each for drought and irrigated conditions. For the experiment 44 elite genotypes collected from various parts of the country and evaluated for drought related growth traits namely Mean productivity (MP), Rate productivity (RP), Drought susceptibility index (DSI), Drought tolerance index (DTI), Tolerance to drought stress (TDS), Relative water content (RWC), Leaf Area (LA), Leaf area Duration (LAD), Crop Growth rate (CGR), Relative growth rate (RGR), Net assimilation rate (NAR) and Harvest index (HI). The 44 genotypes were soaked in water and sown in the pots @ five seeds/pot and three healthy plants were maintained. Randomised block design (RBD) was adopted for the experiment with three replications. The irrigated plants were watered regularly and the for the drought treatment, the watering was stopped at flowering (between 21 to 37 days after sowing).

All the growth analysis parameters namely relative water content (RWC), leaf area (LA), leaf area Duration (LAD), crop Growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and harvest index (HI) were measured at 15 days interval from 23 DAS. Total leaf area per plant was estimated by measuring maximum length (mL) and width (mW) of leaves and multiplying these inputs (mL × mW) by a correction factor of 0.6 derived from the actual leaf area determined with a leaf area meter. The estimations were considered accurate because the differences in correction factor between the two genotypes and the leaf age were very small, so that comparisons between the genotypes and the watering regimes were not significantly biased. The growth analysis components were calculated between sampling dates as follows:

$$RWC = \frac{(\text{Fresh weight} - \text{Dry weight})}{(\text{Turgid weight} - \text{Dry weight})} \times 100$$

$$LAD = \frac{(A_1 + A_2)(t_2 - t_1)}{2}$$

$$CGR = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1}$$

$$NAR = \frac{(W_2 - W_1)(\text{Log}_e A_2 - \text{Log}_e A_1)}{(t_2 - t_1)(A_2 - A_1)}$$

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

where W is the total dry weight, t is the time, A is the total leaf area, WL is the total dry weight of leaves, and 1 and 2 are the stress periods, respectively. P is plant spacing

EXPERIMENTAL RESULTS AND DISCUSSION

Relative Water Content (RWC)

RWC referring to its relation with cell volume, accurately can indicate the balance between absorbed water by plant and consumed through transpiration. The relative water content (RWC) ranged from 65.67 (V 3518) to 84.00 (IPM 306-1) in the irrigated environment and from 58.00 (IPM 02-19) to 79.00 (IPM 9901-10) under the stress environment. Twenty eight genotypes excelled the general mean of 76.32 and twenty four genotypes showed higher means than the general mean of 67.67 for irrigated and stress environments, respectively (Table 1).

The percent reduction in relative water content among the forty four genotypes ranged from 2.26 to 15.93. The minimum reduction of relative water content was recorded by PDM 87 followed by LGG 410. Seventeen genotypes recorded lower reduction percentages than the general mean reduction percent (Figure 1).

Generally, it seems that osmoregulation is one of the main mechanisms preserving turgor pressure in most plant species against water loss from so, it causes plant to continue water absorption and retain metabolic activities. Osmoregulation is one of the main mechanisms preserving turgor pressure in most plant species against water loss from so, it causes plant to continue water absorption and retain metabolic activities. Leaf RWC is of the best growth/ biochemical indices revealing the stress intensity (Alizade, 2002). The rate of RWC in plant with high resistance against drought is higher than others. In other words, plant having higher yields under drought stress should have high RWC. So, based on results, mentioned genotypes which are classified as high and medium yielding genotypes in condition of drought stress, should be of high-content RWC. Decrease in RWC in plants under drought stress may depend on plant vigor reduction and have been observed in many plants (Liu *et al.*, 2002). Under water deficit, cell membrane subjects to changes such as penetrability and decrease in sustainability (Blokhina *et al.*, 2003).

Leaf Area (LA)

It ranged from 263.08 cm2 (IPM 02-19) to 494.56 cm^2 (IPM2K14-9) and 256.56 cm^2 to 417.74 cm2 (IPM 99901-10) for irrigated and stress environments, respectively. Under irrigated environment, twenty four genotypes excelled the general mean value of 423.59 cm^2. Whereas, twenty two genotypes had higher mean values than the general mean of 423.56 cm^2 under stress environment (Table 1).

The percentage deduction in leaf area ranged from 0.15 to 41.14. the minimum leaf area reduction

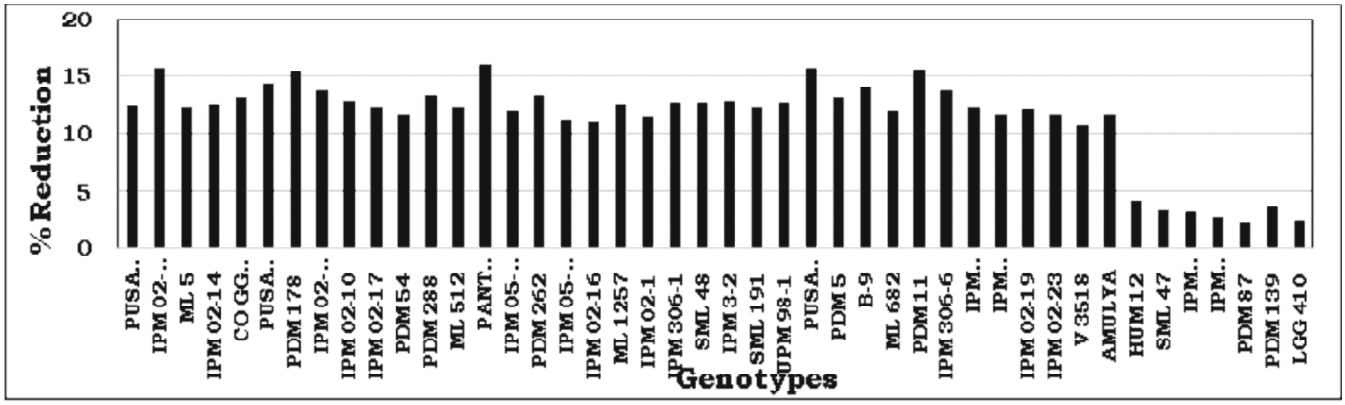

Figure 1: Percent reduction of Relative water content (RWC) of genotypes under stress condition

Table 1
Mean values of mungbean genotypes under irrigated (Control) and stress environments for morpho-physiological characters

		RWC		*LA*		*LAD*		*CGR*		*RGR*		*NAR*		*HI*	
S. No.	*Genotypes*	*C*	*S*	*C*	*S*	*C*	*S*	*C*	*S*	*C*	*S*	*C*	*S*	*C*	*S*
1.	Pusa 9972	82.67	72.33	452.81**	297.49	15.23	14.75	14.79	12.42	0.015	0.009	0.246*	0.183*	20.21	19.37
2.	IPM 02-3 (B)	80.33	67.67	423.59	387.56**	20.75**	19.10**	14.90	12.24	0.003	0.001	0.039	0.013	21.22**	20.78**
3.	ML 5	81.67	71.67	448.63**	316.60	16.95	16.78	15.69	15.23	0.015	0.009	0.217	0.146	24.11**	23.57**
4.	IPM 02-14	79.33	69.33	434.03**	332.98**	17.06	14.56	14.02	13.27	0.017*	0.010	0.240*	0.121	18.89	18.21
5.	CO GG 912	78.00	67.67	423.59	327.53	17.31	13.63	17.64**	15.05*	0.025**	0.012	0.374**	0.157	19.98	19.19
6.	Pusa 9072	78.67	67.33	421.51	319.34	16.75	15.79	14.92	12.71	0.013	0.011	0.198	0.155	24.65**	23.68**
7.	PDM 178	82.33	69.67	436.11**	256.56	13.91	13.76	17.87**	16.84**	0.017*	0.018*	0.299**	0.281**	24.71**	22.97**
8.	IPM 02-03)	80.00	69.00	431.94**	294.87	14.93	14.92	15.05	13.21	0.014	0.012	0.225	0.196**	19.73	17.91
9.	IPM 02-10	80.67	70.33	440.29**	289.31	16.51	15.38	16.96	14.16	0.019	0.017*	0.301**	0.273**	25.03**	23.18**
10.	IPM 02-17	78.67	69.00	431.94**	324.66	17.08	15.55	17.35**	16.32**	0.016	0.014*	0.270*	0.195**	22.19**	21.13**
11.	PDM 54	77.33	68.33	427.77**	346.64**	18.33**	16.12	16.39	15.43*	0.017*	0.009	0.257*	0.143	22.06**	21.20**
12.	PDM 288	77.67	67.33	421.51	292.06	16.31	15.30	17.31**	15.30*	0.012	0.013	0.213	0.218**	20.13	19.81*
13.	ML 512	78.67	69.00*	431.94**	311.15	15.51	14.79	17.08	14.66	0.014	0.009	0.232*	0.153	19.39	18.31
14.	Pant Mung5	75.33	63.33	396.47	283.85	14.92	14.05	16.35	12.49	0.011	0.010	0.167	0.149	16.60	15.91
15.	IPM 05-3-22	78.00	68.67	429.85**	313.85	17.43	15.55	14.88	13.51	0.011	0.009	0.154	0.118	20.23	19.95*
16.	PDM 262	80.33	69.67	436.11**	344.00**	18.06*	17.39*	18.95**	13.52	0.010	0.003	0.133	0.048	22.32**	21.23**
17.	IPM 05-2-8	79.67	70.67	442.37**	305.75	16.02	15.25	15.72	13.13	0.010	0.011	0.143	0.154	19.70	19.44
18.	IPM 02-16	73.00	65.00	406.90	267.53	14.88	13.75	15.43	13.26	0.012	0.009	0.198	0.138	23.64**	22.30**
19.	ML 1257	79.67	69.67	436.11**	305.64	16.19	15.46	15.12	12.62	0.009	0.005	0.129	0.076	19.78	18.87
20.	IPM 02-1	78.33	69.33	434.03**	292.05	15.85	15.82	13.26	12.30	0.011	0.006	0.154	0.112	18.98	18.42
21.	IPM 306-1	84.00	73.33	459.07**	319.34	16.40	16.56	12.42	11.09	0.014	0.018	0.212	0.250**	20.60	19.84*
22.	SML 48	78.33	68.33	427.77**	319.32	16.81	16.29	14.60	12.24	0.008	0.011	0.092	0.116	19.19	18.09
23.	IPM 3-2	77.33	67.33	421.51	305.87	15.96	14.05	13.44	13.14	0.016	0.011	0.228	0.139	19.73	19.13
24.	SML 191	78.33	68.67	429.85**	297.47	15.93	14.95	14.92	11.60	0.010	0.006	0.127	0.080	19.96	19.65
25.	UPM 98-1	71.00	62.00	388.12	387.56**	20.24**	18.53	16.51	14.28	0.007	0.006	0.105	0.070	18.09	17.19
26.	Pusa Bold2	74.33	62.67	392.29	316.59	16.95	15.23	14.58	13.77	0.011	0.006	0.171	0.087	21.59**	19.45
27.	PDM 5	68.00	59.00	369.34	332.98	17.83	16.64	15.46	14.29	0.013	0.009	0.183	0.114	20.57	20.11**
28.	B-9	71.00	61.00	381.86	327.57	17.54	15.96	14.07	13.13	0.010	0.008	0.139	0.091	18.85	18.31
29.	ML 682	66.67	58.67	367.25	319.41	17.10	14.89	15.53	15.05*	0.015	0.015*	0.243*	0.198**	12.98	12.36

Cont. table 1

		RWC		LA		LAD		CGR		RGR		NAR		HI	
S. No.	Genotypes	C	S	C	S	C	S	C	S	C	S	C	S	C	S
30.	PDM 11	79.00	66.67	417.33	256.67	13.74	13.97	17.13	16.32**	0.016	0.015*	0.299**	0.237**	23.17**	22.40**
31	IPM 306-6	70.00	60.33	377.69	295.05	15.80	15.63	12.89	11.75	0.006	0.005	0.078	0.074	19.69	19.07
32	IPM 9901-03	68.00	59.67	373.51	289.33	15.49	14.03	13.10	11.60	0.017*	0.012	0.228	0.173*	15.72	15.24
33.	IPM 9901-125	68.67	60.67	379.77	324.81	17.39	16.38	15.04	13.14	0.008	0.011	0.112	0.130	15.67	15.21
34.	IPM 02-19	66.00	58.00	363.08	346.73**	18.57**	17.16	13.26	12.22	0.008	0.007	0.118	0.098	17.42	16.58
35.	IPM 02-23	68.67	60.67	379.77	292.03	15.64	15.35	15.30	13.70	0.011	0.013	0.202	0.219**	18.99	18.42
36.	V 3518	65.67	58.67	367.25	311.22	16.66	14.96	14.59	14.29	0.008	0.009	0.186	0.148	15.35	14.57
37.	AMULYA	71.33	63.00	394.38	284.00	15.21	13.14	16.83	14.79	0.018*	0.016*	0.381**	0.274**	15.58	14.96
38.	HUM 12	77.67	74.33	465.33**	333.60**	17.86	16.13	16.32	15.96*	0.015	0.014*	0.217	0.187**	19.49	19.26
39.	SML 47	77.33	74.67	467.41**	318.56	17.06	17.54*	14.54	14.01	0.012	0.010	0.164	0.147	19.41	19.20
40.	IPM 9901-10	81.67	79.00	494.54**	417.74**	22.37**	19.56**	15.68	15.58*	0.012	0.009	0.145	0.101	20.37	20.18**
41.	IPM 2K14-9	81.33	79.00	494.54**	318.55	17.06	16.93	15.18	14.01	0.012	0.014*	0.157	0.178*	20.55	20.33**
42.	PDM 87	74.00	72.33	452.81**	348.62**	18.67**	17.12	15.56	15.12*	0.013	0.007	0.177	0.115	21.15**	20.97**
43.	PDM 139	80.00	77.00	482.02**	378.67**	20.28**	17.74**	15.43	15.23*	0.014	0.011	0.178	0.124	19.47	19.30
44.	LGG 410	79.33	77.33	484.11**	348.62**	18.67**	17.20	17.34**	16.41**	0.017*	0.010	0.256*	0.157	19.89	19.72
General Mean		76.32	67.67	423.59	318.18	16.94	15.76	15.44	13.87	0.013	0.010	0.195	0.149	19.93	19.20
SE	1.28	0.94	1.38	6.61	1.07	1.30	1.12	0.83	0.002	0.003	0.018	0.013	0.62	0.08	
CD (P = 0.05)*		2.19	1.22	2.45	10.53	1.12	1.63	1.76	1.01	0.004	0.004	0.035	0.022	0.84	0.55
CD (P = 0.01)**		2.21	1.62	2.63	11.18	1.33	1.83	1.85	2.32	0.006	0.009	0.102	0.036	1.03	0.87

RWC- relative water content; LA – Leaf area; LAD- Leaf area duration; CGR - Crop growth Rate; RGR- Relative growth Rate; NAR - Net assimilation rate; HI- Harvest Index

C – Irrigated (Control) environment

S – Stress environment

was noted in the genotype UPM 98-1 and the maximum was recorded in the genotype PDM 178. Twenty genotypes recorded lower percent of reduction when compared to the mean percent of reduction (Figure 2).

Leaf area is a critical parameter controlling many biological and physical processes associated with vegetation (Running, 1990; Bonan, 2003). Water stress reduces photosynthesis by decreasing leaf area. Leaf area index (LAI) is one of the most important crop parameters that determine radiation intercepted by the crop canopy, and therefore has strong impacts on crop canopy photosynthesis and transpiration.

KazemGhassemi-Golezani *et al.*, 2014; Serdar and Demirsoy, 2006 have reported that if the increase in leaf area more than usual, it causes competition for light. Any change in canopy leaf area is accompanied by modifications in crop productivity.

Leaf Area Duration (LAD)

LAD varied from 13.74 days (PDM 11) to 22.37 days (IPM 9901-10) under irrigated environment. Twenty one genotypes excelled the general mean of 16.94. under stress environment, LAD ranged from 13.14 days (Amulya) to 19.53 days(IPM 9901-10). Twenty genotypes had higher mean values than the general mean of 15.76 days (Table 1).

The minimum percent of reduction was observed in the genotype IPM 02-03 (0.04) followed by IPM2K14-9 (0.73). whereas, the maximum reduction was recorded in the genotype IPM 02-14 (21.26). Twenty two genotypes showed lower reduction percentages than the mean reduction percentage of 6.71 (Figure 3).

Crop Growth Rate (CGR)

Crop growth rate (CGR) as the rate of dry matter production per unit area. Crop growth ranged from 12.42 (IPM 306-1) to 18.95 g $m^{-2}day^{-1}$(PDM 262) and

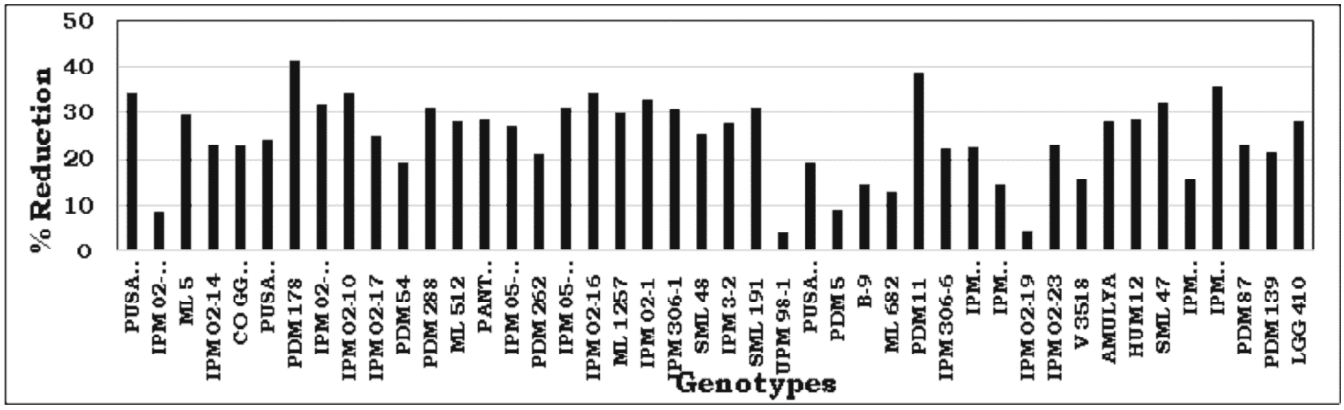

Figure 2: Percent reduction of Leaf Area (cm2) of genotypes under stress condition

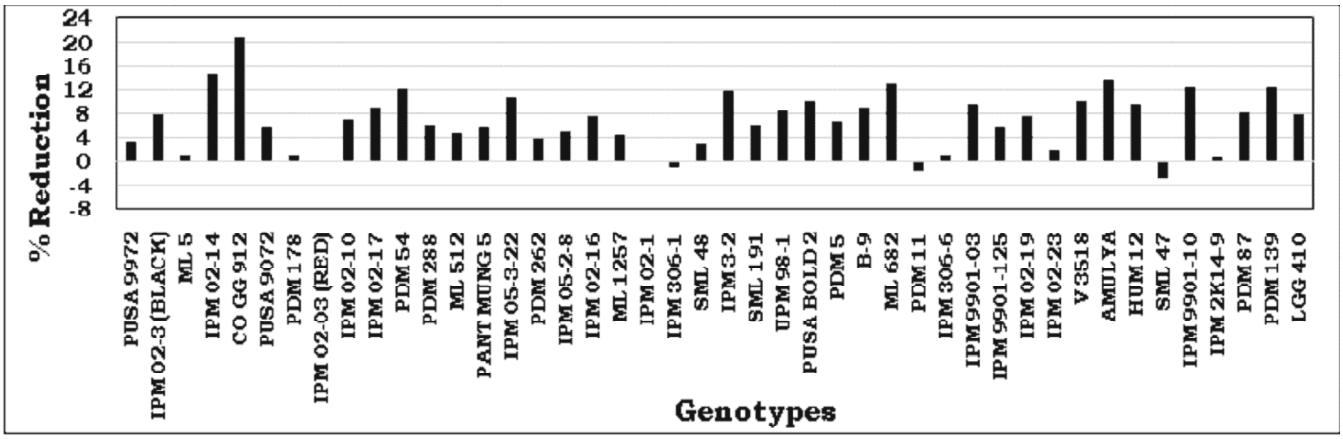

Figure 3: Percent reduction of Leaf Area Duration (LAD) of genotypes under stress condition

from 11.09 (IPM 306-1) to 16.84 g m^{-2} day^{-1} (PDM 178) under irrigated and stress environments, respectively. Under irrigated environment, nineteen genotypes excelled the general mean of 18.95 and twenty one genotypes showed higher mean values than the general mean of 16.84 g m^{-2} day^{-1}under stress environment (Table 1).

For crop growth, the percent reduction ranged from 0.64 (IPM 9901-10) to 28.69 (PDM 262). Twenty three genotypes showed lower reduction percentages than the mean reduction percentage of 10.02 (Figure 4)

Relative Growth Rate (RGR)

Relative growth rate (RGR) was defined as the rate of dry matter accumulation per unit of existing dry matter. Under irrigated environment, the range varied from 0.003 (IPM 02-3) to 0.025 mg g^{-1} day^{-1} (CoGG 912) and nineteen genotypes had higher mean values compared to the general mean of 0.013. whereas, under stress environment the mean among the genotypes ranged from 0.001(IPM 02-3) to 0.018 mg g^{-1} day^{-1} (IPM 306-1) and seventeen genotypes had higher mean values than the general mean of 0.010mg g^{-1} day^{-1} (Table 1).

Among the 44 genotypes, the percent reduction in RGR ranged from –43.47 (IPM 9901-125 to 68.77 (PDM 262). Twenty two genotypes recorded lower percent of reduction than the mean reduction percent of 18.50 (Figure 5).

Net Assimilation Rate (NAR)

The net assimilation rate is a measure of net photosynthesis of leaves in crop community. Under irrigated environment, the NAR varied from 0.039 (IPM 02-3) to 0.0381 g cm^{-2} day^{-1} (Amulya). Whereas, under stress environment it ranged from 0.013 (IPM 02-3) to 0.281g cm^{-2} day^{-1} (PDM 178). The general means for irrigated and stress environments were 0.195 and 0.149, respectively (Table 1).

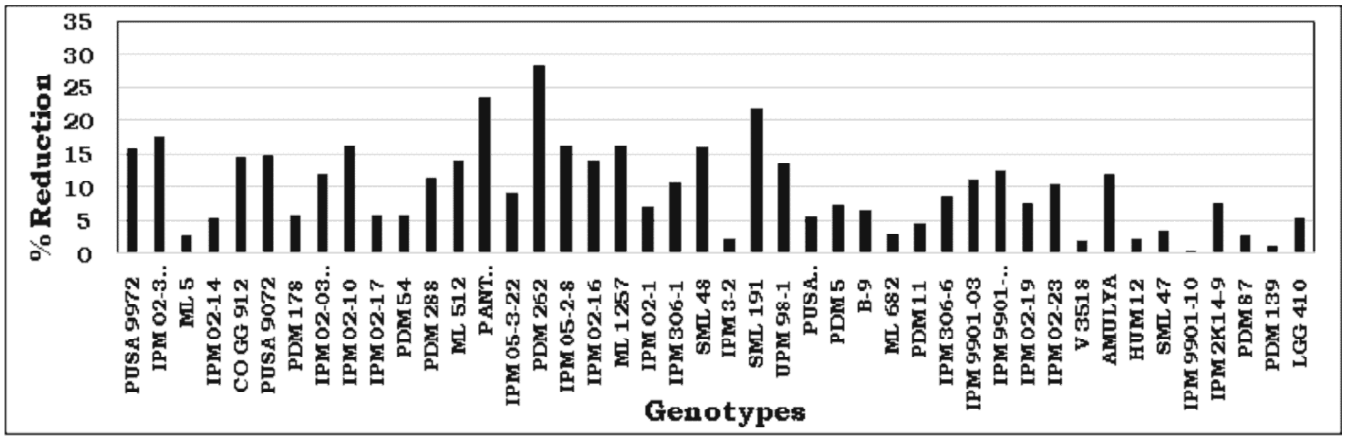

Figure 4: Percent reduction of Crop Growth Rate (CGR) of genotypes under stress condition

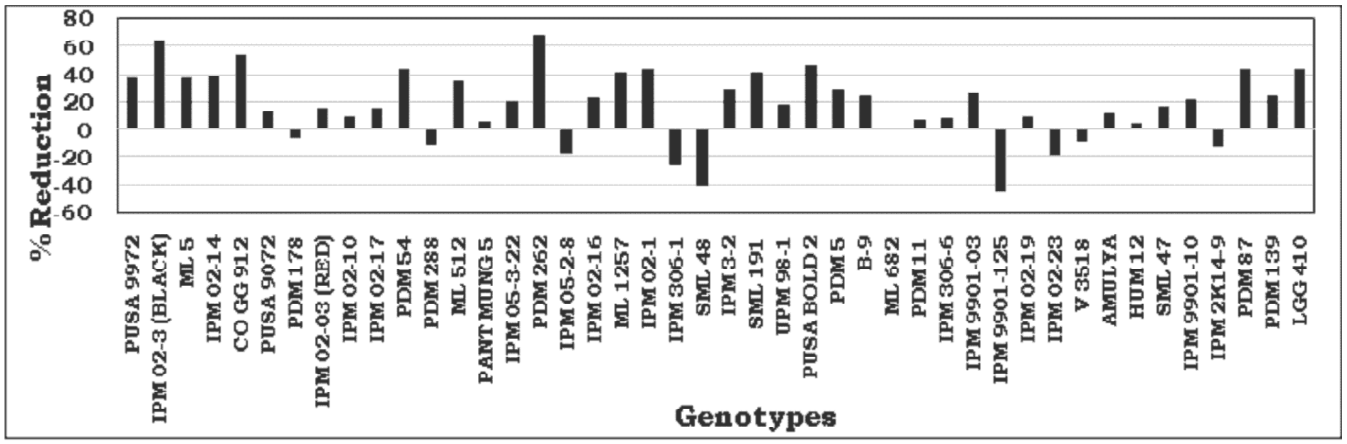

Figure 5: Percent reduction of Relative Growth Rate (RGR) of genotypes under stress condition

The reduction for NAR ranged from –25.45 (SML 48) to 67.38 (IPM 02-3) percent. Twenty genotypes showed lower reduction percentages than the mean reduction percentage of 23.12 g cm^{-2} day^{-1} for NAR (Figure 6).

The NAR declined at later growth stages (reproductive stage) which may be attributed to excessive mutual shading as the LA was maximum during this period and increased number of old leaves could have lowered the photosynthetic efficiency [Mondal*et al*., 2011, 2012].

Harvest Index (HI)

Harvest Index ranged from 12.98 (ML 682) to 25.03 (IPM 02-10) and from 12.36 (ML 682) to 23.68 (Pusa 9072) for irrigated and stress environments, respectively. Twenty one genotypes had higher mean values than the general mean of 19.93 under irrigated environment. Whereas, under the stress environment twenty three genotypes excelled the general mean of 19.20 (Table 1).

The minimum percent of reduction was observed in the genotype PDM 87 (0.82) followed by PDM 139 (0.85). Whereas, the maximum reduction was recorded in the genotype Pusa Bold 2 (9.93). Twenty three genotypes showed lower reduction percentages than the mean reduction percentage of 3.62 (Figure 7).

The efficiency of dry matter partitioning is represented by harvest index (HI) which is the ratio between yield and total above ground biomass. Harvest index of mungbean is about 0.3 (without shed leaves) (Singh and Saxena *et al.* 1980; Thomas *et al.* 2004). Hay (1995) suggested that crops with low HI should be targeted for improvement, while maintaining biomass production. Harvest index is affected by a plant's phenology. In many tropical legumes, HI is maximised when they are grown at photoperiods below their critical photoperiod because of their rapid ontogenetic development (Lawn and Williams 1987). When such legumes are grown at latitudes lower than their normal

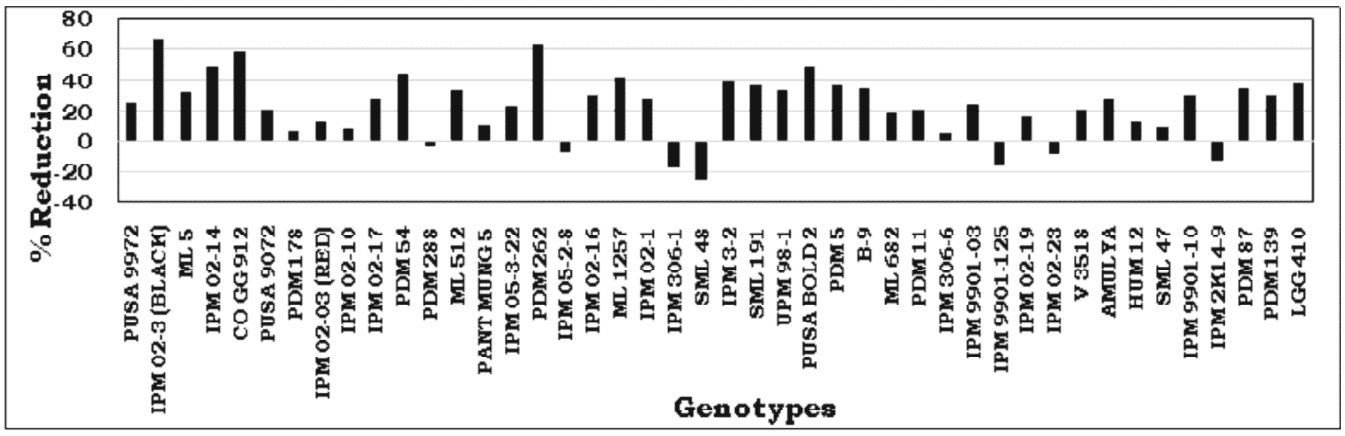

Figure 6: Percent reduction of Net Assimilation Rate (NAR) of genotypes under stress condition

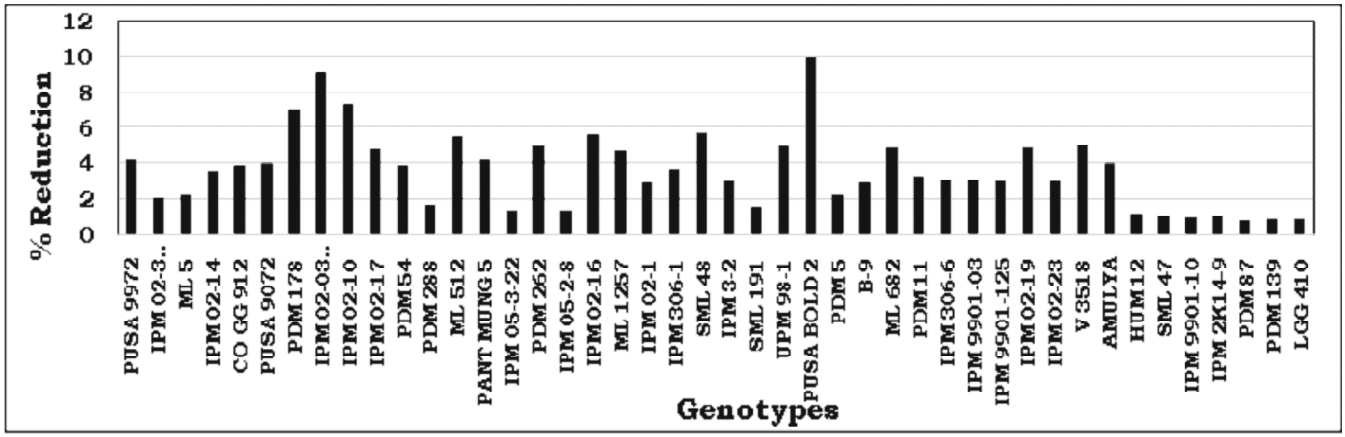

Figure 7: Percent reduction of Harvest Index (HI) of genotypes under stress condition

adaptation this also usually results in a higher HI (Lawn 1989). A more directed analysis of HI in mungbean is required to gain insight into how future increases in this trait can be achieved.

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