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Effect of drought on morphophysiological and biochemical traits in green gram (*Vigna radiata* (L.) R. Wilczek) genotypes at different developmental stages

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Abstract
The present study was conducted with 25 mungbean genotypes in Randomized Block Design with 3 replicates per variety with three levels of stress treatment i.e. Control (no stress), drought induced at vegetative stage (25 days after sowing) and drought induced at reproductive stage (35 days after sowing). Analysis of variance indicated sufficient amount of variability for fifteen morphophysiological and biochemical characters. The genotypes such as Samrat, Banka local Mung, KL 4 and IPM 205-7 showed higher mean in desirable direction for days to fifty percent flowering, days to maturity, primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index, proline content, leaf area, chlorophyll content and seed yield per plant. Higher values of GCV and PCV were recorded for traits like Pods per plant, protein content, leaf area and seed yield per plant under control condition, while under drought at vegetative and reproductive stage most of the traits such as cluster per plant, pods per plant, harvest index, protein content, proline content, leaf area and seed yield per plant showed higher values of GCV and PCV. Genetic advance was recorded highest for leaf area under control as well as stress condition. Traits like days to fifty percent flowering, days to maturity, pods per plant, protein content, proline content, relative water content, leaf area, chlorophyll content and seed yield per plant exhibited moderate to high heritability under control condition, while under stress condition, both during vegetative and reproductive stage, heritability estimates were high for days to maturity, cluster per plant, pods per plant, seed per pod, 100 seed weight, protein content, proline content, relative water content, leaf area, chlorophyll content and seed yield per plant. From the pooled genotypic correlation analysis during both the years, positive and significant association was depicted by Primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index, proline content, leaf area and chlorophyll content.

Keywords: Variability, heritability, genetic advance, correlation, morphophysiological traits and biochemical traits

Introduction

Mungbean [*Vigna radiata* (L.) Wilczek, 2n=22] is the third most important pulse crop grown in India belongs to family *Fabaceae or leguminaceae*. It is nutritionally rich having 25% protein, 56.7% carbohydrate, 1.3% fat, 4.1% fibre and mineral like calcium 124 mg / l00g of edible portion, vitamin A (83 IU), thiamine (0.72), riboflavin (0.15) and nicotinic acid (2.4) (DES, MOAEF, GOI). Mungbean can grow in rain-fed conditions at high temperatures (27–30 °C), with low humidity and moderate rainfall ranging from 60 to 80 cm and can thrive under drought conditions (Dutta and Bera, 2008; Ahmad *et al*., 2015) [12, 2]. But the response of mungbean varieties for different morphophysiological trait under drought condition varies during different developmental stages depending on stress duration, growth stage and variety of the crop.

Drought is a complex phenomenon that is related to higher moisture and temperature stress. Several breeding programme has been developed for drought tolerance in mungbean but till now, the progress is not significant. Therefore knowledge of drought tolerance mechanism at various developmental, physiological, biochemical and molecular level will help to develop drought tolerant cultivar. Hence, understanding of mungbean response towards drought will help in improving its adaptation towards drought and will also expand the area of legume cultivation in drought prone region.

The phenotypic expression of a character is the resultant of interactions between genotypes and environment. Therefore, to know the true breeding behavior of the genotype, total variation needs to be partitioned into variance due to genotype (Heritable) and variance due to environment (non-heritable) which will increase the efficiency of selection. Estimation of genetic variability along with heritability and genetic advance gives an idea of possible improvement of the character through selection. Drought and seed yield is a complex character which is governed by several quantitative traits and the environment in which it is grown. The knowledge of association of yield component traits with other yield and drought tolerant traits through correlation studies will also enhance the efficiency of selection.

Materials and Methods

The present was carried out during summer, 2020 & 2021 at the Research Farm, ICAR Research Complex for Eastern Region Research Centre, Plandu, Ranchi. The experiment was performed with 25 mungbean genotypes in randomized block design with three replications and three treatments *viz*., Control, drought stress at vegetative stage and drought stress at reproductive stage. Initially the land was prepared by ploughing and harrowing to a fine tilth before defining the plot. Each genotype was sown manually with a spacing of 30 cm between rows and 15 cm between plants within rows. Thinning was done to leave single plant per hill. The fertilizer was applied at the rate of 25 kg N, 50 kg P_2O_5 and 25 kg K in the form of urea, Di-Ammonium phosphate and Murate of potash respectively. Irrigation was done as per the recommended package of practices in no stress (Control) Plot, while for stress at vegetative stage and reproductive stage, irrigation was restricted at 25 days after sowing and 35 days after sowing respectively by removal of irrigation for 15 days. Weeding and plant protection measures were taken up as and when needed during the crop growth period, as per the standards recommended package of practices. The genotype performance was assessed by recording observations on the following attributes from five randomly selected plants from each row for Plant height (cm), Primary branches per plant, Clusters per plant, Pods per plant, Seeds per pod, 100 seed weight (g), Seed yield per plant (g), Harvest index (%), Relative water content (%), Leaf area (cm^2), Proline content (%), Protein content %) and chlorophyll content. Days to 50% flowering and days to maturity was recorded on the basis of plant population.

The data recorded for all the characters were subjected to analysis of variance as per the formula suggested by Panse and Sukhatme (1957) [6]. The genotypic, phenotypic and environmental components were estimated as explained according to Johnson *et al.* (1955) [19]. The coefficients of phenotypic and genotypic variance were calculated by the formula suggested by Burton (1953) [7], while GCV and PCV were categorized as low, moderate and high according to Shivasubramanian and Menon (1973) [35]. Heritability in broad sense was calculated by using the formula proposed by Allard (1960) [3] and it was categorized as demonstrated by Robinson *et al.* (1951) [31]. Expected genetic advance was calculated by using the methodology suggested by Allard (1960) [3] at 5 per cent selection intensity using the constant 'K' as 2.06. The expected genetic advance as expressed in per cent of mean was calculated by the method suggested by Johnson *et al.* (1955) [19] and it was categorized as suggested by Johnson *et al.* (1955) [19].

Results and Discussion

The mean performances of twenty five mungbean genotypes under control and stress condition in two different stages are depicted as follows for fifteen morphological and biochemical parameters. Under control condition, highest mean in desirable direction was depicted by genotypes KL 4 (36.33) for days to fifty percent flowering, KL 4 (63.00) for days to maturity, IPM 2-3 (52.37) for plant height, Pant mung (4.07) for primary branches per plant, Pusa Baishakhi (27.11) for cluster per plant, Banka Local mung (23.51) for pods per plant, Samrat (12.05) for seed per pod, Samrat (4.73) for 100 seed weight, KL 4 (1.04) for harvest index, Pusa Baishakhi (10.25) for protein content, Samrat (3.37) for proline content, IPM 2-14 (91.69) for relative water content, Samrat (94.89) for leaf area, Banka local mung (48.40) for chlorophyll content and Banka local mung (9.40) for seed yield per plant.

Under drought stress at vegetative stage condition, greater value of mean in recommendable direction was expressed by KL 4 & Samrat (30.67) for days to fifty percent flowering, KL 4 (54.00) for days to maturity, MH 565 (41.86) for plant height, Samrat (1.87) for primary branches per plant, Samrat (8.47) for cluster per plant, Samrat (14.59) for pods per plant, Samrat (8.11) for seed per pod, Samrat (4.12) for 100 seed weight, ML 818 (2.57) for harvest index, Pusa Baishakhi (6.51) for protein content, Samrat (4.46) for proline content, IPM 2-14 (84.02) for relative water content, Samrat (70.42) for leaf area, Samrat (50.30) for chlorophyll content and Samrat (4.11) for seed yield per plant.

Days to fifty percent flowering (KL-4, 34.33), days to maturity (KL-4, 59.00), plant height (IPM 2-3 & MH 565, 43.98), primary branches per plant (LGG 524, 2.69), cluster per plant (Samrat, 11.01), pods per plant (IPM 205-7, 12.48), seed per pod (Banka local mung, 7.35), 100 seed weight (Samrat, 4.07), harvest index (Banka local mung & Samrat, 0.40), protein content (Pant Mung, 7.56), proline content (Samrat, 4.82), relative water content (IPM 2-14, 86.45), leaf area (Samrat, 83.24), chlorophyll content (Samrat, 51.98) and seed yield per plant (IPM 205-7, 3.52) had higher value of mean in desirable direction under drought at reproductive stage.

However, it was seen that under stress condition, especially when drought was induced at vegetative stage, genotypes flowered early as compared to those when stress was applied at reproductive stage and control condition. Under Similar trend was observed for days to maturity. These finding were in accordance with the study of Bangar *et al.* (2019) [10], Bharadwaj *et al.* (2018) [9], Baroowa *et al.* (2016) [8], Raina *et al.* (2016) [32], Ranawake *et al.* (2012) [29], Allahmoradi *et al.* (2011) [6], Mafakheri *et al.* (2010) [22] and Dutta and Bera (2008) [12]. Other morphological traits such as plant height, primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index and seed yield per plant showed significant decrease when exposed to drought condition at both vegetative and reproductive stage as compared to control condition which may be due to impairment in cell division and cell expansion which cause deterioration in cell turgidity, ultimately leading to reduction in growth and yield. These findings were supported by the work of Bangar *et al.* (2019) [10], Bharadwaj *et al.* (2018) [9], Eshwaran and Anbananda (2018) [15], Baroowa *et al.* (2016) [8], Raina *et al.* (2016) [32], Ranawake *et al.* (2012) [29] and Mafakheri *et al.* (2010) [22].

Relative water content showed significant decrease under stress condition due to negative impact of drought on water potential of leaves as compared to control condition. Similar result was obtained by Bangar *et al.* (2019) [10], Chawdhary *et al.* (2017) [11] and Parvin *et al.* (2015) [28]. There was significant variation observed in biochemical traits such as protein and proline content. It was seen that under stress condition, there was increase in proline content and reduction in protein content as compared to control condition during both vegetative and reproductive stage stress. The reason for increase in proline content is due to its osmolyte nature, which maintains osmotic potential and protects plant from harmful effect of low water potential. These findings were supported by the study of Bangar *et al*. (2019) [10], Bharadwaj *et al.* (2018) [9], Kabbadj *et al.* (2017) [21] and Silvestre *et al.* (2017) [36].

Reduction in leaf area and chlorophyll content was also observed during vegetative and reproductive stage stress as compared to control condition. Reduction in leaf area seems to be drought avoiding mechanism, since reduction in leaf area will lead to reduce water loss through transpiration. Similar findings were recorded by Bangar *et al.* (2019) [10], Bharadwaj *et al*. (2018) [9], Alderfasi *et al.* (2017) [5] and Allahmoradi *et al.* (2011) [6].

Analysis of variance for various characters studied under different conditions of control, drought at vegetative stage and drought at reproductive stage indicated sufficient amount of variability (table 1). Under control condition, higher values of GCV and PCV were recorded for traits like Pods per plant, protein content, leaf area and seed yield per plant. In case of drought at vegetative and reproductive stage most of the traits such as cluster per plant, pods per plant, harvest index, protein content, proline content, leaf area and seed yield per plant showed higher values of GCV and PCV (table 2 to 3). These findings were supported by the studies of Owusu *et al.* (2021) [25], Garg *et al* (2017) [16], Sarath chandra *et al*. (2017) [23], Abraha *et al.* (2015) [4], Rathor *et al*. (2015) [30], Ahmad *et al.* (2014) [1], Narshimhulu *et al*. (2013) [24], Mia *et al.* (2010) [23] and Vinay *et al.* (2010) [38].

Heritability and genetic advance represents the extent of heritable variation for achieving desirable gains in selection programme. The broad sense heritability depicts the effectiveness of selection by estimating heritable portion of variance. Most of the characters exhibited moderate to high heritability for the traits like days to fifty percent flowering, days to maturity, pods per plant, protein content, proline content, relative water content, leaf area, chlorophyll content and seed yield per plant under control condition. In case of stress condition, both during vegetative and reproductive stage, heritability estimates were high for days to maturity, cluster per plant, pods per plant, seed per pod, 100 seed weight, protein content, proline content, relative water content, leaf area, chlorophyll content and seed yield per plant. High heritability for some of the traits like indicated that the traits are generally governed by additive gene effects and improvement for these traits could be made by simple phenotypic selection. Similar findings were reported by Sarath chandra *et al*. (2017) [33], Vir and Singh (2016) [37], Abraha *et al.* (2015) [4], Ahmad *et al.* (2015) [2], Kumar *et al.* (2022) [20], Rathor *et al.* (2015) [30], Ahmad *et al.* (2014) [1], Narshimhulu *et al*. (2013) [24], Zaid *et al.* (2012) [40], Mia *et al.* (2010) [23] and Vinay *et al.* (2010) [38].

Under control as well as stress condition, genetic advance higher for leaf area and low value was recorded for the remaining traits such as days to fifty percent flowering, days to maturity, plant height, primary branches per plant, cluster per plant, pods per pant, seed per pod, 100 seed weight, harvest index, protein content, proline content, relative water content, chlorophyll content and seed yield per plant. It was in accordance with the studies of Abraha *et al.* (2015) [4] and Zaid *et al.* (2012) [4].

The knowledge of correlation among various characters is necessary when there is requirement for selection of these traits for simultaneous improvement. If two favourable characters are associated, selection for one character will automatically be good enough for the other. Strength and direction of correlation in different character combinations depend on the nature of experimental material and environmental condition in which they have been studied. From the table 4-5, it was observed that generally seed yield per plant was strongly and positively associated with the yield components in both the years. In the year 2020 and 2021, positive and significant association was depicted by Primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index, proline content, leaf area and chlorophyll content (Table 4-5). Similar findings were reported by Bangar *et al*. (2019) [10], Ghimire *et al.* (2018) [18], Parihar *et al.* (2018) [27], Swathi *et al*. (2017) [34], Vir and Singh (2016) [37].

In general, days to 50% flowering showed positive and significant correlation with days to maturity while negative and significant correlation was observed for primary branches per plant, pods per plant, seed per pod, 100 seed weight, harvest index, proline content, leaf area and chlorophyll content during both the years. Days to maturity manifested positive and significant correlation with protein content during 2020. This finding is in accordance with Bangar *et al*. (2019) [10] and Zaid *et al.* (2012) [4]. Plant height was positively and significantly associated with 100 seed weight, relative water content and leaf area. Primary branches per plant showed positive and significant association with cluster per plant, pods per plant, seed per pod, proline content, leaf area, chlorophyll content and seed yield. Clusters per plant was significantly and positively associated with pods per plant, seed per pod, proline content, leaf area, chlorophyll content and seed yield. The genotypic association of pods per plant was positive and significant with seed per pod, 100 seed weight, harvest index, proline content, leaf area, chlorophyll content and seed yield. *S*eeds per pod showed positive and significant association with 100 seed weight, proline content, leaf area, chlorophyll content and seed yield. 100 seed weight manifested positive and significant correlation with proline content, leaf area, chlorophyll content and seed yield. Harvest index exhibited positive and significant association with seed yield. Similar findings were reported by Kumar *et al.* (2022) [20], Dhunde *et al.* (2021) [14], Yoseph *et al.* (2020) [39], Ghimire *et al.* (2018) [18], Parihar *et al.* (2018) [27], Garg *et al.* (2017) [16], Swathi *et al.* (2017) [34] and Vir and Singh (2016) [37] for all morphological characters studied in mungbean.

Biochemical characters such as protein content depicted positive and significant association with with relative water content, while proline content exhibited positive and significant correlation with leaf area, chlorophyll content and seed yield. Leaf area had positive and significant association with chlorophyll content and seed yield while chlorophyll content depicted positive and significant association with seed yield per plant. Bangar *et al.* (2019) [10], Baroowa *et al.* (2016) [8] and Abraha *et al.* (2015) [4] reported similar findings. Hence the response of mungbean genotypes under drough condition both morphophysiological and biochemical, will contribute for further studies related to drought tolerance in mungbean.

Table 1: Analysis of variance of fifteen quantitative and biochemical parameters under control, drought at vegetative stage and drought at reproductive stage during summer 2020 and 2021

Year	2020									2021								
Stage	**Control**			**VEG**			**REP**			**Control**			**VEG**			**REP**		
SOV	**T**	**R**	**E**	**T**	**R**	**E**	**T**	**R**	**E**	**T**	**R**	**E**	**T**	**R**	**E**	**T**	**R**	**E**
df	24	2	48	24	2	48	24	2	48	24	2	48	24	2	48	24	2	48
DFF	82.85**	1.33	3.89	90.13**	8.92	2.94	86.71**	25.97	30.03	63.69**	9.88	3.53	66.75**	3.00	3.08	64.58**	1.12	2.49
DM	81.34**	4.01	4.11	62.35**	1.65	2.86	80.86**	3.29	2.95	56.73**	9.21	3.52	53.85**	7.61	2.12	77.15**	4.85	2.55
PH	41.31**	74.34	15.79	41.32**	74.33	15.79	41.31**	74.33	15.79	56.11**	12.25	24.98	56.11**	12.25	24.98	56.11**	12.65	24.99
PBP	0.94**	0.30	0.40	0.10**	0.01	0.04	0.54**	0.09	0.08	0.97**	0.41	0.25	0.20**	0.19	0.07	0.62**	0.03	0.06
CPP	50.95*	53.54	45.91	10.36**	0.66	0.31	9.98**	0.39	0.40	9.45**	0.51	1.95	11.56**	1.01	0.71	9.73**	0.01	0.19
PPP	38.08**	0.16	2.42	25.97**	1.97	1.73	20.58**	0.53	1.28	40.33**	12.21	5.48	15.28*	23.96	7.82	16.49**	0.12	2.08
SPP	3.28**	2.45	0.83	2.81**	0.12	0.27	2.38**	0.07	0.11	2.59	0.01	2.63	2.85**	1.07	0.24	1.58*	0.29	0.75
100 SW	0.11**	0.01	0.02	0.40**	0.05	0.01	0.53**	0.07	0.02	0.10**	0.02	0.01	0.52**	0.03	0.02	0.43**	0.02	0.01
SY	6.09**	0.03	0.39	0.10**	0.07	0.04	1.63**	0.04	0.10	6.45**	1.96	0.58	1.21*	1.90	0.62	1.31**	0.01	0.16
HI	0.07**	0.05	0.02	2.06**	0.16	0.14	0.04**	0.02	0.02	0.17**	0.19	0.06	2.85*	0.62	2.48	0.13*	0.19	0.07
RWC	33.78**	13.27	5.11	44.59**	19.88	5.85	25.01**	6.49	2.21	55.63**	3.21	5.97	73.03**	16.21	8.33	56.18**	4.99	4.70
LA	588.53**	189.32	94.17	375.96**	19.66	5.75	455.17**	5.18	14.39	930.22**	2.56	9.42	421.62**	27.77	8.21	566.04**	0.71	10.59
PROT	12.76**	1.31	0.66	6.15**	1.89	0.58	6.89**	1.17	0.68	6.16**	0.45	1.66	4.06**	0.14	0.90	4.78**	0.08	0.83
PROL	0.46**	0.14	0.07	2.10**	0.80	0.19	2.43**	1.08	0.19	0.75**	0.56	0.17	1.01**	0.82	0.16	1.73**	0.56	0.14
CC	29.43**	6.67	3.00	33.09**	6.36	2.27	56.26**	1.36	3.49	24.91**	2.95	1.03	30.12**	1.04	4.32	66.14**	4.47	3.81

DFF- Days to 50% flowering, DM- Days to maturity, PH- Plant height, PBP - Primary branches per plant, CPP- Clusters per plant, PPP- Pods per plant, SPP- Seed per pod, 100 SW- 100 Seed weight, SY- Seed yield per plant, HI – Harvest index, RWC – Relative water content, LA- Leaf area, PROT- Protein content, PROL- Proline content, CC- Chlorophyll content

SOV- source of variation, df- degrees of freedom, T- treatment, R-replication, E-error

Control: No stress, Veg: Drought stress at vegetative stage, Rep: Drought stress at reproductive stage

** - Significant at 1.0 per cent level of probability, * - Significant at 5.0 per cent level of probability

Table 2: Genetic parameters for fifteen quantitative and biochemical parameters under control, drought at vegetative stage and drought at reproductive stage during summer 2020

Parameter	Condition	DFF	DM	PH	PBP	CPP	PPP	SPP	100 SW	HI	PROT	PROL	RWC	LA	CC	SY
	C	26.32	25.74	8.51	0.18	1.85	11.89	0.82	0.03	0.01	4.03	0.13	9.56	164.79	8.81	1.90
Genetic variance	V	29.06	19.83	8.51	0.02	3.35	8.08	0.85	0.13	0.02	1.86	0.64	12.91	123.40	10.27	0.64
	R	18.89	25.97	8.51	0.15	3.19	6.44	0.76	0.17	0.01	2.07	0.75	7.60	146.92	17.59	0.51
	C	30.21	29.85	24.30	0.58	47.26	14.30	1.66	0.05	0.04	4.70	0.20	14.67	258.95	11.81	2.29
Phenotypic variance	V	32.01	22.69	24.30	0.06	3.66	9.81	1.12	0.15	0.07	2.44	0.83	18.76	129.16	12.54	0.78
	R	48.92	28.92	24.30	0.24	3.59	7.72	0.87	0.19	0.02	2.75	0.94	9.81	161.32	21.08	0.61
GCV	C	11.01	7.06	6.52	13.98	15.08	22.79	9.00	4.02	18.63	33.41	18.77	3.86	20.37	6.99	22.80
	V	13.98	7.22	7.94	9.81	41.74	43.09	16.12	10.84	38.04	41.41	27.22	4.97	29.56	7.39	43.09
	R	9.98	7.54	7.45	19.59	48.09	41.52	15.69	12.48	33.75	33.04	28.19	3.74	25.61	9.99	41.53
PCV	C	11.79	7.64	11.02	25.07	76.30	25.01	12.81	5.45	32.71	36.06	23.29	4.78	25.54	8.10	25.01
	V	14.67	7.73	13.42	16.99	43.63	47.49	18.54	11.62	71.01	47.50	31.04	5.99	30.24	8.18	47.49
	R	16.05	7.96	12.58	24.65	51.02	45.46	16.78	13.13	60.05	38.10	31.59	4.25	26.84	10.94	45.47
H^2b	C	87.13	86.20	35.00	31.10	3.90	83.10	49.30	54.50	32.40	85.90	64.90	65.20	63.60	74.60	83.10
	V	90.80	87.40	35.00	33.30	91.50	82.30	75.60	87.00	28.70	76.00	76.90	68.80	95.50	81.90	82.30
	R	38.60	89.80	35.00	63.10	88.80	83.40	87.40	90.40	31.60	75.20	79.60	77.50	91.10	83.40	83.40
GA	C	9.87	9.71	3.56	0.49	0.55	6.48	1.31	0.26	0.14	3.83	0.59	5.14	21.09	5.28	2.59
	V	10.58	8.58	3.56	0.17	3.61	5.31	1.65	0.69	0.15	2.45	1.44	6.14	22.37	5.98	1.49
	R	5.56	9.95	3.56	0.64	3.47	4.77	1.68	0.81	0.10	2.57	1.59	5.00	23.83	7.89	1.35
GAM	C	21.11	13.50	7.95	16.05	6.14	42.81	13.02	6.11	21.85	63.77	31.17	6.41	33.48	12.44	42.81
	V	27.44	13.91	9.68	11.67	82.24	80.54	28.88	20.82	41.98	74.39	49.18	8.49	59.52	13.79	80.55
	R	12.77	14.73	9.07	0.82	93.37	93.38	30.22	24.44	39.08	59.02	51.81	6.78	50.35	18.80	78.14

DFF- Days to 50% flowering, DM- Days to maturity, PH- Plant height, PBP - Primary branches per plant, CPP- Clusters per plant, PPP- Pods per plant, SPP- Seed per pod, 100 SW- 100 Seed weight, HI – Harvest index, PROT- Protein content, PROL- Proline content, RWC – Relative water content, LA- Leaf area, CC- Chlorophyll content, SY- Seed yield per plant

GCV- Genotypic coefficient of variance, PCV – Phenotypic coefficient of variance, H^2b- Heritability, GA – Genetic advance, GAM- Genetic advance as percent of mean, C- Control (No stress), V- Drought at vegetative stage, R- Drought at reproductive stage

Table 3: Genetic parameters for fifteen quantitative and biochemical parameters under control, drought at vegetative stage and drought at reproductive stage during summer 2021

Parameter	Condition	DFF	DM	PH	PBP	CPP	PPP	SPP	100 SW	HI	PROT	PROL	RWC	LA	CC	SY
	C	20.05	17.74	10.37	0.24	2.50	11.62	0.01	0.03	0.04	1.49	0.19	16.55	306.93	7.32	1.86
Genetic variance	V	21.22	17.24	10.37	0.04	3.62	2.48	0.87	0.17	0.03	1.05	0.28	21.57	137.81	8.60	0.20
	R	20.69	24.87	10.37	0.19	3.18	4.81	0.28	0.14	0.02	1.32	0.53	17.16	185.15	20.77	0.38
	C	23.59	21.25	35.36	0.49	4.45	17.10	2.62	0.04	0.10	3.16	0.36	22.53	316.36	10.27	2.74
Phenotypic variance	V	24.31	19.36	35.36	0.12	4.33	10.31	1.11	0.19	2.52	1.96	0.44	29.90	146.01	12.92	0.82
	R	23.19	27.41	35.36	0.24	3.37	6.88	1.03	0.15	0.08	2.15	0.67	21.87	195.74	24.59	0.55
GCV	C	9.55	5.84	7.34	16.09	19.64	22.42	1.18	4.01	27.81	21.76	18.95	5.01	26.30	6.29	22.43
	V	11.99	6.69	8.95	14.48	45.16	24.15	16.34	12.36	65.41	31.14	17.77	6.30	30.63	6.84	24.15
	R	10.15	7.30	8.45	22.89	49.68	34.99	9.64	11.33	43.19	28.49	23.42	5.61	28.81	10.95	34.99
PCV	C	10.35	6.39	13.56	22.88	26.20	27.21	16.16	4.88	46.29	31.60	25.89	5.84	26.70	7.45	27.21
	V	12.84	7.09	16.53	23.60	49.41	49.17	18.49	13.05	580.31	42.55	22.20	7.41	31.53	8.38	49.19
	R	10.74	7.67	15.61	26.11	51.17	41.89	18.49	11.89	88.64	36.38	26.42	6.34	29.62	11.91	41.89
H^2b	C	85.00	83.40	29.30	49.50	56.20	67.90	0.50	67.40	36.10	47.40	53.60	73.50	97.00	71.20	67.90
	V	87.30	89.00	29.30	37.60	83.50	24.10	78.10	89.70	1.30	53.60	64.00	72.10	94.90	66.50	24.10
	R	89.20	90.70	29.30	76.90	94.20	69.80	27.20	90.80	23.70	61.30	78.50	78.50	94.60	84.50	69.80
GA	C	8.51	7.93	3.60	0.71	2.44	5.79	0.02	0.28	0.23	1.74	0.66	7.18	35.54	4.70	2.31
	V	8.86	8.07	3.59	0.26	3.58	1.59	1.69	0.79	0.04	1.54	0.87	8.13	23.49	4.93	0.45
	R	8.85	9.78	3.59	0.78	3.56	3.77	0.57	0.73	0.15	1.85	1.33	7.56	27.26	8.63	1.06
GAM	C	18.14	10.98	8.19	23.31	30.32	38.08	0.17	6.78	34.41	30.85	28.57	8.83	53.36	10.93	38.08
	V	23.09	13.01	9.91	18.30	85.02	24.44	29.75	24.11	15.19	46.96	29.29	11.02	61.31	11.49	24.43
	R	19.74	14.33	9.44	41.35	99.33	60.22	10.35	22.24	43.35	45.96	42.74	10.24	57.72	20.73	60.23

DFF- Days to 50% flowering, DM- Days to maturity, PH- Plant height, PBP - Primary branches per plant, CPP- Clusters per plant, PPP- Pods per plant, SPP- Seed per pod, 100 SW- 100 Seed weight, HI – Harvest index, PROT- Protein content, PROL- Proline content, RWC – Relative water content, LA- Leaf area, CC- Chlorophyll content, SY- Seed yield per plant
GCV- Genotypic coefficient of variance, PCV – Phenotypic coefficient of variance, H^2b- Heritability, GA – Genetic advance, GAM- Genetic advance as percent of mean, C- Control (No stress), V- Drought at vegetative stage, R- Drought at reproductive stage

Table 4: Pooled Genotypic correlation coefficient of seed yield per plant with other characters in twenty five mung bean genotypes under control, drought at vegetative stage and drought at reproductive stage during summer 2020

	DFF	DM	PH	PBP	CPP	PPP	SPP	100 SW	HI	PROT	PROL	RWC	LA	CC	SY
DFF	1.00	0.76**	-0.02	-0.31**	-0.07	-0.42**	-0.40**	-0.41**	-0.16*	0.21**	-0.56**	0.17**	-0.39**	-0.45**	-0.38**
DM		1.00	-0.09	-0.30**	-0.04	-0.30**	-0.35**	-0.30**	-0.04	0.23**	-0.56**	0.06	-0.39**	-0.50**	-0.29**
PH			1.00	-0.06	0.09	0.12	-0.01	0.01*	-0.64**	0.03	0.02	0.19**	0.10	0.03	0.12
PBP				1.00	0.34**	0.46**	0.38**	0.29	0.28**	0.05	0.40**	-0.08	0.34**	0.39**	0.48**
CPP					1.00	0.31**	0.19**	0.23**	0.09	0.10	0.24**	-0.01	0.25**	0.17**	0.29**
PPP						1.00	0.56**	0.55**	0.49**	-0.12	0.51**	-0.21**	0.54**	0.43**	0.98**
SPP							1.00	0.54**	0.30**	-0.18**	0.51**	-0.26**	0.43**	0.42**	0.53**
100 SW								1.00	0.33**	-0.22**	0.55**	-0.29**	0.39**	0.45**	0.49**
HI									1.00	-0.05	0.23**	-0.19**	0.22**	0.15*	0.48**
PROT										1.00	-0.35**	0.15*	-0.21**	-0.29**	-0.08
PROL											1.00	-0.21**	0.52**	0.65**	0.46**
RWC												1.00	-0.05	-0.10	-0.18**
LA													1.00	0.43**	0.53**
CC														1.00	0.41**
SY															1.00

DFF- Days to 50% flowering, DM- Days to maturity, PH- Plant height, PBP - Primary branches per plant, CPP- Clusters per plant, PPP- Pods per plant, SPP- Seed per pod, 100 SW- 100 Seed weight, HI – Harvest index, PROT- Protein content, PROL- Proline content, RWC – Relative water content, LA- Leaf area, CC- Chlorophyll content, SY- Seed yield per plant
** - Significant at 1.0 per cent level of probability, * - Significant at 5.0 per cent level of probability

Table 5: Pooled Genotypic correlation coefficient of seed yield per plant with other characters in twenty five mung bean genotypes under control, drought at vegetative stage and drought at reproductive stage during summer 2021

	DFF	DM	PH	PBP	CPP	PPP	SPP	100 SW	HI	PROT	PROL	RWC	LA	CC	SY
DFF	1.00	0.89**	-0.04	-0.32**	-0.36**	-0.36**	-0.24**	-0.43**	-0.14*	0.05	-0.67**	-0.06	-0.56**	-0.45**	-0.35**
DM		1.00	-0.01	-0.36**	-0.29**	-0.29**	-0.18**	-0.33**	-0.14*	0.00	-0.66**	-0.03	-0.48**	-0.43**	-0.29**
PH			1.00	-0.03	0.23**	-0.01	0.05	0.05	-0.14*	0.08	0.07	0.04	0.16*	0.10	-0.02
PBP				1.00	0.42**	0.38**	0.23**	0.29**	0.11	0.05	0.38**	0.10	0.47**	0.37**	0.39**
CPP					1.00	0.49**	0.36**	0.66**	0.02	-0.05	0.57**	0.05	0.68**	0.50**	0.48**
PPP						1.00	0.22**	0.47**	0.24**	-0.02	0.33**	-0.03	0.53**	0.35**	0.99**
SPP							1.00	0.41**	0.04	-0.20*	0.37**	0.01	0.29**	0.28**	0.20**
100 SW								1.00	0.07	-0.10	0.57**	0.16*	0.49**	0.46**	0.43**
HI									1.00	0.01	0.04	-0.10	0.02	-0.06	0.22**
PROT										1.00	-0.13	0.20**	0.09	-0.11	-0.01
PROL											1.00	0.10	0.57**	0.62**	0.30**
RWC												1.00	0.14*	0.25**	-0.04
LA													1.00	0.51**	0.54**
CC														1.00	0.32**
SY															1.00

DFF- Days to 50% flowering, DM- Days to maturity, PH- Plant height, PBP - Primary branches per plant, CPP- Clusters per plant, PPP- Pods per plant, SPP- Seed per pod, 100 SW- 100 Seed weight, HI – Harvest index, PROT- Protein content, PROL- Proline content, RWC – Relative water content, LA- Leaf area, CC- Chlorophyll content, SY- Seed yield per plant

** - Significant at 1.0 per cent level of probability, * - Significant at 5.0 per cent level of probability

Conclusion

From the above findings it can be concluded that, under stress condition especially when drought was induced at vegetative stage, genotypes flowered as well matured early as compared to those when stress was applied at reproductive stage followed control condition. Other morphological traits such as plant height, primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index seed yield per plant, Protein content, leaf area, relative water content and Chlorophyll content showed significant reduction when exposed to drought condition at both vegetative and reproductive stage as compared to control condition which may be due to impairment in cell division and cell expansion causing deterioration in cell turgidity, ultimately leading to reduction in growth and yield. It was seen that under stress condition, there was increase in proline content during both vegetative and reproductive stage because proline acts as a osmolyte which maintains osmotic potential and protects plant from harmful effect of low water potential therefore increase in proline content may be considered as drought tolerance mechanism. From analysis of variance, sufficient amount of variability was observed for various morphophysiological and biochemical characters studied under different conditions of control, drought at vegetative stage and drought at reproductive stage. Under control condition, higher values of GCV and PCV were recorded for traits like Pods per plant, protein content, leaf area and seed yield per plant, whereas traits such as cluster per plant, pods per plant, harvest index, protein content, proline content, leaf area and seed yield per plant showed higher values of GCV and PCV under drought stress during vegetative and reproductive stage. Under stress condition, characters such as days to maturity, cluster per plant, pods per plant, seed per pod, 100 seed weight, protein content, proline content, relative water content, leaf area, chlorophyll content and seed yield per plant showed high heritability indicating that the traits are governed by additive gene effects and improvement for these traits could be made by simple phenotypic selection. Correlation analysis enables selection of related traits for simultaneous improvement. Seed yield per plant showed positive and significant association with Primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index, proline content, leaf area and chlorophyll content. For improvement of seed yield under drought condition, selection can be directly done on the basis of traits like Primary branches per plant, cluster per plant, pods per plant, seed per pod, 100 seed weight, harvest index, proline content, leaf area and chlorophyll content. Thus selection of genotypes like Samrat, Banka local, IPM 205-7 and KL 4 could be selected as a parents in drought resistance breeding for better physiological and biochemical traits associated with drought. Drought at vegetative stage stress leads to severe reduction in yield as compared to those where drought is induced at reproductive stress. So with limited number of irrigation, it must be ensured not to induce stress at vegetative stage.

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