D-5554
[1-5]

RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Morpho-physiological Variability and Yield Determinants for Drought Tolerance in Blackgram [*Vigna mungo* (L.) Hepper]

D. Bordoloi, A. Sarma, D. Sarma

10.18805/ag.D-5554

ABSTRACT

Background: An understanding of genotypic differences to water deficit stress can help in identifying genotypes that can tolerate drought with reasonable grain yield. The present experiment was conducted to assess the physiological and yield-related parameters of ten black gram genotypes under water deficit stress environment.

Methods: We evaluated ten diverse black gram genotypes for yield and drought-related traits under water deficit stress (3.98% moisture content) and non-stress (14.35% moisture content) environments in separate pot experiments following complete randomized designs with three replications during *Kharif* 2015-16.

Result: Analysis of variance revealed significant genetic variation among the genotypes for almost all the observed traits. The traits *viz*., 100-seed weights, proline content, pods per plant, relative leaf water content, chlorophyll content and seed yield per plant showed high heritability estimates coupled with a high genetic advance under both the environments. Based on grain yield efficiency index, the genotypes AKU 10-6, COBG 10-06 and NDUK 13-4 were drought efficient with high yield under stress condition.

Key words: GYEI, Proline, Stress, Variability.

INTRODUCTION

The environmental changes can influence crop growth and thereby yield in nature due to abiotic and biotic stresses. These abiotic and biotic stresses bring changes in yield due to physiological and biochemical parameters from a mild to the larger extent (Baroowa and Gogoi, 2013). Among the different stresses, water deficit stress occurs in over 1.2 billion hectares of rainfed agricultural land, reducing crop yield worldwide (Boyer, 1982). More than 87% of the area under pulses is presently rainfed and moisture stress is the main reason for crop failure or for low yield realization. Water deficit stress can lead to various physiological peculiarities in plants, getting in the way of their growth and production (Banerjee *et al*., 2021). In fact, this abiotic stress appearing at the reproductive phase of plants may pose serious threats to the maturing of leguminous crops by means of leaf area and chlorophyll content ultimately culminating into poor production (Banerjee *et al*., 2021). Improved varieties of different pulse crops hold promise to increase productivity by 20-25% (Ali and Gupta, 2012). An understanding of genotypic differences to water deficit stress can help in identifying genotypes that can tolerate drought with reasonable seed yield. The present experiment was conducted to assess the physiological and yield-related parameters of ten black gram genotypes under water deficit stress environment.

MATERIALS AND METHODS

Two pot experiments were conducted with ten black gram genotypes during *Kharif* 2015-2016 in the net house of the Department of Plant Breeding and Genetics, Assam Agricultural University, Assam. The pot were filled with a mixture of 4 parts finely powdered upland field soils of sandy

Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat-785 013, Assam, India.

Corresponding Author: D. Bordoloi, Department of Plant Breeding and Genetics, Assam Agricultural University, Jorhat-785 013, Assam, India. Email: diboshjrt@gmail.com

How to cite this article: Bordoloi, D., Sarma, A. and Sarma, D. (2022). Morpho-physiological Variability and Yield Determinants for Drought Tolerance in Blackgram [*Vigna mungo* (L.) Hepper]. Agricultural Science Digest. DOI: 10.18805/ag.D-5554.

Submitted: 11-01-2022 **Accepted:** 07-07-2022 **Online:** 16-07-2022

loam texture acidic in reaction (pH 6.5) and 1 part vermicompost supplemented with N: P: K @ 15:35:10 kg ha^{-1} and a soil pesticide Carbofuran 3G @ 30 kg ha^{-1} calculated on surface area basis. The ten black gram genotypes - AKU 10-6, MU 44, COBG 10-06, VBG 11-31, SBC 47, SBC 40, PU 11-14, NDUK 13-4, MU 06 and AKU 11-8 were laid out in completely randomized design (CRD) with three replications in each experiment. One day ahead of sowing, the pots were wetted up to field capacity (~ 20% moisture content). The non-stress pots were maintained by watering at weekly intervals while water deficit stress was imposed at the vegetative stage by withholding irrigation till appearance of wilting symptoms in 80% of the pots, which coincided with flower bud initiation (33 DAS) and thereafter stress was released by irrigating the pots once in the same way as done in the non-stress experiment. The soil moisture content of the pots from a depth of 15 cm was estimated by gravimetric method once at 33 DAS in both the experiments (Dastane, 1972). The average soil moisture contents in the water deficit stress and non-stress condition were 3.98±0.25

and 14.35±0.24 %, respectively. The plants were observed for leaf area (cm^2) (LA), chlorophyll content (mg g^{-1}FW) (CHL), proline content (µ mg g^{-1}) (PC), relative leaf water content (%) (RLWC), days to flower bud initiation (DFBI), plant height (cm) (PH), number of branches per plant (BR), clusters per plant (CL), pods per plant (PP), pod length (cm) (PL), number of seeds per pod (SP), 100-seed weights (g) (HSW) and seed yield per plant (g) (SY). The data generated were subjected to environment wise and pooled analysis of variance (ANOVA) as per CRD taking replications, genotypes and environments as fixed effects in Windostat v.9.2.

RESULTS AND DISCUSSION

Analysis of variance

The environment wise and pooled ANOVA revealed significant genotypic differences for all the traits except days to flower bud initiation (Table 1). The mean sum of squares due to G × E interaction was significant for all the characters except for chlorophyll content, days to first bud initiation and number of branches per plant suggesting a differential behaviour of the genotypes to stress and non-stress environment for majority of the traits.

Mean performance of physiological traits of the genotypes

The water deficit stress significantly reduced all the physiological traits of the black gram genotypes (Table 2a). The genotype MU 06 was found to be adapted to the water-stress environment as indicated by the lowest pooled mean leaf area (22.0 cm^2). The resulting smaller leaf area transpires less water and hence this can be considered as the first line of defense against drought (Gurumurthy, *et al*., 2019). The chlorophyll content of all the genotypes reduced significantly under the water deficit stress as compared to the non-stress environment. The mean chlorophyll content under non-stress and water deficit stress environment varied from 2.8 mg/g (MU 06) to 4.4 mg/g (SBC 40) and 1.3 mg/g (MU 06) to 2.2 mg/g (AKU 10-6), respectively. The decrease in chlorophyll content due to moisture deficit stress was also reported by Rao *et al*. (2015) in black gram. The proline content ranged from 6.7 (MU 44) to 10.8 µ mole g^{-1} (AKU 10-6) under water stress and 3.9 (MU 06) to 10.6 µ mole g^{-1} (SBC 40) under the non-stress environment. A significant increase in proline was observed in response to water stress in black gram. Proline is a multifunctional amino acid and accumulates in many plant species in response to an array of abiotic stresses (Gurumurthy, *et al*., 2019). The trait relative leaf water content (RLWC) decreased from 73.8% under non-stress to 49.7% under water deficit stress. The presence of higher RLWC in tolerant genotypes indicates their more ability to retain water, possibly due to better osmo-regulation (Gambao *et al*., 1991). The genotype VBG 11-31 with the highest RLWC of 64.0% under stress environment suggested its ability to retain more water among the ten genotypes selected for the present study.

Mean performance of yield and its components of the genotypes

The yield and its components traits decreased when water deficit stress was imposed during the flowering stage but there was significant variation among the genotypes (Table 2a and 2b). The water deficit stress significantly reduced plant height varying from 26.6 (MU 06) to 38.8 (VBG 11-31) as against the range from 39.1 (COBG10-06) to 48.0 (VBG11-31) under non-stress condition. However, the water stress during the vegetative stage, in particular, is the most detrimental in terms of height (Baroowa *et al*., 2016). Under the non-stress environment, the branches per plant ranged from 7.4 (AKU 11-8) to 10.8 (COBG 10-06) whereas under

Table 1: Environment wise and pooled analyses of variance for grain yield and its attributes of the 10 black gram genotypes.

Character	Non-stress			Stress			Pooled				
	Mean squares			Mean squares			Mean squares				
	GEN (9)	Error (20)	CV (%)	GEN (9)	Error (20)	CV (%)	ENV (1)	GEN (9)	ENV*GEN (9)	Pooled error(40)	CV (%)
LA	0.30**	0.04	3.99	13.30**	2.08	2.91	918.85 **	28.57 **	25.16 **	2.55	5.98
CHL	0.52**	0.03	5.02	0.19**	0.01	6.52	29.85 **	0.45 *	0.29	0.16	14.5
PC	10.72**	0.02	5.91	7.41**	0.25	9.01	111.90 **	4.11 **	14.01 **	0.26	7.17
RLWC	74.32**	4.62	2.91	298.05**	7.65	5.56	8743.03 **	165.01 **	207.33 **	6.14	4.01
DFBI	9.51	4.66	8.93	4.91	3.30	4.93	187.27 **	8.04	6.38	3.98	5.17
PH	24.04**	4.40	4.99	40.57**	11.95	10.4	1158.61 **	38.51 **	26.12 **	8.18	7.6
BR	3.19**	0.54	8.16	0.97**	0.17	7.80	210.45 **	3.61 **	0.54	0.35	8.37
CL	3.21**	0.07	8.28	3.28**	0.15	10.58	66.85 **	1.33 **	2.27 **	0.11	9.24
PP	28.63**	1.53	9.73	13.81**	1.04	14.23	459.54 **	32.52 **	9.93 **	1.28	11.41
PL	0.46**	0.03	3.84	0.07**	0.02	3.87	9.33 **	0.34 **	0.19 **	0.03	3.87
SP	0.19**	0.07	5.19	0.78**	0.11	10.44	64.79 **	0.73 **	0.37 **	0.08	6.6
HSW	1.52**	0.02	2.48	1.56**	0.01	1.81	0.66 **	3.06 **	0.04 **	0.01	2.18
SY	0.73**	0.06	7.74	0.18**	0.04	16.67	66.74 **	0.61 **	0.32 **	0.05	10.15

Figures within brackets are degrees of freedom.

water stress it varied from 4.6 (AKU 11-8) to 6.4 (COBG 10-06. The mean number of clusters per plant was 2.6 under stress as against 4.7 under non-stress environment. The pods per plant ranged from 7.0 (MU 06) to 17.9 (SBC 40) under the well watered environment and 3.6 (MU 06) to 11.7 (COBG 10-06) under water deficit stress. The genotypes SBC 40 and COBG 10-06 recorded the highest number of pods per plant in well watered and water deficit stress,

Table 2a: Mean performance for physiological and yield attribute traits of the 10 black gram genotypes.

Genotype	LA			CHL			PC			RLWC			DFBI			PH			BR		
	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM
AKU10-6	35.0	23.5	29.2	3.5	2.7	3.1	4.6	10.8	7.7	75.2	49.1	62.2	39.3	35.0	37.2	41.3	35.3	38.3	9.4	5.6	7.5
MU44	31.2	25.8	28.5	3.3	1.9	2.6	6.2	6.7	6.5	68.7	35.3	52.0	37.7	37.0	37.3	43.7	33.1	38.4	8.5	5.0	6.7
COBG10-06	33.0	22.1	27.6	3.4	2.1	2.8	4.5	9.6	7.1	71.8	38.3	55.1	40.7	38.0	39.3	39.1	31.6	35.3	10.8	6.4	8.6
VBG11-31	31.6	25.3	28.4	3.3	2.0	2.6	6.0	7.2	6.6	78.3	64.0	71.2	41.7	36.7	39.2	48.0	38.8	43.4	8.6	4.7	6.6
SBC47	29.7	23.4	26.6	3.7	2.1	2.9	6.3	7.0	6.7	72.6	52.9	62.8	41.7	37.7	39.7	40.9	33.4	37.2	7.8	5.1	6.5
SBC40	35.0	20.3	27.7	4.4	2.0	3.2	10.6	7.4	9.0	69.4	55.8	62.6	43.7	36.3	40.0	41.1	37.5	39.3	9.7	5.3	7.5
PU11-14	32.4	21.7	27.1	3.4	2.1	2.8	4.8	8.8	6.8	85.3	36.4	60.9	40.3	37.0	38.7	41.1	32.1	36.6	8.5	4.7	6.6
NDUK13-4	28.2	20.7	24.4	3.6	1.9	2.7	5.9	9.3	7.6	74.8	50.3	62.6	40.7	35.7	38.2	40.3	35.0	37.7	9.2	5.4	7.3
MU06	24.0	20.1	22.0	2.8	1.7	2.2	3.9	10.7	7.3	71.4	59.7	65.6	40.0	39.3	39.7	45.4	26.6	36.0	10.0	5.6	7.8
AKU11-8	26.0	24.9	25.5	3.2	2.0	2.6	4.8	7.3	6.1	70.8	54.9	62.9	38.0	35.7	36.8	39.3	29.1	34.2	7.5	4.6	6.0
CD (5%) ENV			0.8			0.2			0.3			1.3			1.0			1.5			0.3
GEN	3.0	2.5	1.9	0.3	0.2	0.5	0.9	0.9	0.6	3.7	4.8	2.9	ns	Ns	2.3	3.6	5.9	3.3	1.3	0.7	0.7
G × E			2.6			-			0.8			4.1			ns			4.7			ns

[NS: Non-stress; S: Stress; PM: Pooled mean].

Table 2b: Mean performance for yields and its components of the 10 black gram genotypes.

Genotype	CL			PP			PL			SP			HSW			SY		
	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM	NS	S	PM
AKU10-6	4.0	3.3	3.7	15.8	9.4	12.6	4.2	3.9	4.1	5.8	4.3	5.1	5.7	5.7	5.7	3.5	1.6	2.5
MU44	6.9	2.1	4.5	10.2	6.4	8.3	3.9	3.4	3.6	5.0	3.3	4.2	4.9	4.8	4.9	3.0	1.2	2.1
COBG10-06	5.2	2.6	3.9	14.1	11.4	12.8	4.3	3.8	4.0	5.4	2.6	4.0	4.5	4.1	4.3	3.2	1.3	2.2
VBG11-31	4.7	2.6	3.6	11.1	5.9	8.5	4.9	3.8	4.4	5.0	3.4	4.2	4.5	4.4	4.4	3.3	1.2	2.2
SBC47	5.3	2.9	4.1	13.2	6.5	9.9	4.3	3.9	4.1	5.6	3.4	4.5	3.9	3.8	3.8	3.5	1.1	2.3
SBC40	5.0	2.5	3.7	17.9	6.1	12.0	4.9	3.9	4.4	5.7	3.0	4.3	5.9	5.8	5.9	3.9	0.8	2.4
PU11-14	3.2	2.6	2.9	13.4	7.4	10.4	5.1	3.7	4.4	5.3	3.0	4.1	5.0	4.8	4.9	3.4	1.1	2.3
NDUK13-4	3.9	2.6	3.2	13.7	8.1	10.9	4.8	3.8	4.3	5.2	3.3	4.3	5.5	5.0	5.3	3.4	1.3	2.3
MU06	3.8	2.6	3.2	7.0	3.6	5.3	4.6	3.7	4.1	4.9	3.3	4.1	5.8	5.5	5.6	2.0	0.7	1.3
AKU11-8	5.0	2.3	3.7	10.6	6.7	8.6	4.3	3.8	4.0	5.0	2.6	3.8	5.9	5.7	5.8	3.2	1.0	2.1
CD (5%) ENV			0.2			0.6			0.1			0.2			0.1			0.1
GEN	0.7	0.5	0.4	2.1	1.8	1.3	0.3	0.3	0.2	0.4	0.6	0.3	0.2	0.2	0.1	0.4	0.3	0.3
G × E			0.6			1.9			0.3			0.5			0.2			0.4

Table 3: Grain yield efficiency indices (GYEI) of the ten black gram genotypes along with their mean seed yield under water stress.

Genotype	Mean seed yield (g) under stress	GYEI	Remark
AKU 10-6	1.55[a]	1.49	*DE*
COBG 10-06	1.26[ab]	1.10	*DE*
NDUK 13-4	1.26[ab]	1.17	*DE*
MU 44	1.22[bc]	1.00	*DE*
VBG 11-31	1.19[bcd]	1.10	*DE*
SBC 47	1.14[bcde]	1.10	*DE*
PU 11-14	1.12[bcdef]	1.07	*DE*
AKU 11-8	1.01[bcdefg]	0.89	*I*
SBC 40	0.79[gh]	0.86	*I*
MU 06	0.67[h]	0.37	*DI*

Values with the same superscript are statistically at par. (*DE*: Drought efficient, *I*: Intermediate and *DI*: Drought inefficient).

Table 4: Estimates of genetic parameters from environment wise and pooled ANOVAs.

Parameter	Environment	LA	CHL	PC	RLWC	PH	BR	CL	PP	PL	SP	HSW	SY
Range	Non-stress	23.96-35.02	2.77-4.43	3.85-10.57	68.66-85.33	39.11-48.00	7.45-10.78	3.22-6.89	7.00-17.89	3.87-5.07	4.93-5.83	3.90-5.93	2.02-3.94
	Stress	20.11-25.79	1.69-2.70	6.69-10.80	35.31-64.00	26.56-38.78	4.56-6.44	2.11-3.33	3.55-11.44	3.37-3.88	2.55-4.33	3.77-5.77	0.67-1.55
	Pooled	22.04-29.24	2.23-3.20	6.05-8.97	51.98-71.15	34.22-43.39	6.00-8.61	2.89-4.50	5.28-12.78	3.62-4.39	3.79-5.08	3.83-5.85	1.34-2.52
Mean	Non-stress	30.60	3.45	5.76	73.82	42.03	8.98	4.70	12.69	4.53	5.31	5.16	3.23
	Stress	22.78	2.04	8.49	49.68	33.25	5.23	2.59	7.16	3.74	3.23	4.95	1.12
	Pooled	26.69	2.75	7.12	61.75	37.64	7.11	3.64	9.93	4.14	4.27	5.06	2.18
GCV(%)	Non-stress	11.53	11.80	32.41	11.55	6.08	10.47	21.71	23.68	8.34	5.56	13.74	14.66
	Stress	8.41	14.36	18.19	34.60	9.29	9.86	11.09	13.74	3.43	14.67	14.53	20.14
	Pooled	7.80	8.00	11.24	8.33	5.97	10.37	12.37	22.99	5.49	7.71	14.10	14.04
PCV(%)	Non-stress	12.86	12.82	33.64	11.91	7.87	13.29	23.24	25.60	9.18	6.85	13.96	16.53
	Stress	10.59	15.96	19.13	35.04	13.94	12.57	15.28	13.96	5.87	18.00	14.65	26.17
	Pooled	8.53	11.60	11.98	8.65	7.41	11.43	13.44	23.91	6.00	8.61	14.14	15.24
h^2_{bs}	Non-stress	89.72	92.00	96.34	96.97	77.35	78.76	93.00	92.49	90.84	81.21	98.42	88.42
	Stress	80.16	90.01	95.10	98.72	66.66	78.44	72.57	98.41	66.35	81.43	99.18	76.98
	Pooled	83.61	47.54	88.10	92.83	64.96	82.32	84.72	92.43	83.78	80.25	99.35	84.85
GA,% of mean	Non-stress	23.72	24.31	66.77	23.80	12.54	21.56	44.73	48.78	17.19	11.46	35.71	30.20
	Stress	17.49	29.60	37.47	71.28	19.14	20.32	22.84	28.31	7.07	30.22	38.08	41.50
	Pooled	14.70	11.36	21.74	16.54	9.92	19.39	23.46	45.53	10.36	14.23	28.94	26.64

respectively. Anitha *et al*. (2015) also reported that pod number decreased under water deficit stress in black gram with significant variation among the genotypes. The seeds yield per plant ranged from 2.02 g (MU 06) to 3.93 g (SBC 40) in non-stress environment and from 0.67 (MU 06) to 1.55 (AKU 10-6) under water deficit stress. The genotype AKU 10-6 performed the best under both the environments with the lowest mean difference. According to Baroowa and Gogoi (2016) yield loss caused by drought was the highest in plants receiving stress during the early reproductive stage.

Based on the grain yield efficiency index, the ten genotypes were classified as drought efficient (>1.00), intermediate (0.50-1.00) and inefficient (<0.50) [Table 3]. The drought efficient genotypes *viz*., AKU 10-6, COBG 10-06 and NDUK 13-4 exhibited mean grain yield performance at par with each other, the former being the best under moisture deficit stress condition.

Coefficients of variability

The genotypic coefficient of variability for the traits ranged from 5.6 for seeds per pod to 32.4% for proline content under the non-stress environment and from 3.4 for pod length to 34.6% for RLWC under stress environment (Table 4). The traits like chlorophyll content, RLWC, plant height, seeds per pod, 100-seed weights and grain yield per plant had greater GCV estimates under stress than the non-stress environment. These results provided the evidence that these traits showed more variation under stress environment, suggesting scope for selection for these traits under stress environment. These observations are in agreement with the findings of Manggoel *et al*. (2012).

The higher PCV values than their corresponding GCV estimates by narrow margins for all the traits in both the environments indicated that selection for improvement of such characters based on phenotypes would be rewarding to improve the present black gram genotypes. Similar results have been reported by Atta *et al*. (2008).

Heritability and genetic advance

In the present experiment, high heritability estimates were recorded for chlorophyll content, proline content, relative leaf water content, pods per plant and 100-seed weights in both non-stress and stress environments. The results are in agreement with Noor *et al.* (2003) who also reported the high estimates of heritability for these traits. Thus, a direct selection for these traits would be effective in breeding for high-yielding black gram varieties adapted to stress and non-stress environments.

In the present investigation, the high heritability estimates in conjunction with high genetic advance were observed for 100-seed weights, proline content, pods per plant, relative leaf water content, chlorophyll content and seed yield per plant under both the environments. These results are in agreement with Riaz and Chwodhry (2003). In our study, the heritability estimate for seeds per pods was low, coupled with the low genetic advance under the non-stress environment whereas a high heritability with high genetic advance observed under stress environment for this trait. Collaku (1994) reported a differential expression of heritability with the genetic advance in drought stress and the normal environment in many traits in chickpea which was attributed to different sets of alleles and possibly different loci expressed under different environments.

CONCLUSION

Differential behaviour of the genotypes to stress and non-stress environment for the majority of the traits would provide scope for formulating efficient selection criteria for drought tolerance in black gram. The genotype AKU 10-6 would be suitable for moisture stress condition because it is early flowering and has the highest performance for seed yield, proline and relative leaf water content.

Conflict of interest: None.

REFERENCES

Ali, M. and Gupta, S. (2012). Carrying capacity of Indian agricultural pulse crops. Current Science. 102(6): 874-881.

Anitha, Y., Vanaja, M., Sunitha, V., Sowmya, P., Sathish, P., and Kumar, G.V. (2015). Performance of blackgram genotypes under moisture deficit stress-variability in physiological and yield contributing attributes. International Journal of Current Science. 17: 82-89.

Atta, B.M., Haq, M.A. and Shah, T.M. (2008). Variation and inter-relationships of quantitative traits in chickpea (*Cicer arietinum* L.). Pakistan Journal of Botany. 40: 637-647.

Banerjee, P., Venugopalan, V.K., Nath, R., Althobaiti, Y.S., Gaber, A., Al-Yasi, H., and Hossain, A. (2021). Physiology, growth, and productivity of spring-summer black gram [*Vigna mungo* (L.) Hepper] as influenced by heat and moisture stresses in different dates of sowing and nutrient management conditions. Agronomy. 11: 2329.

Baroowa, B. and Gogoi, N. (2013). Biochemical changes in two *Vigna* spp. during drought and subsequent recovery. Indian Journal of Plant Physiology. 18(4): 319-325.

Baroowa, B. and Gogoi, N. (2016). Morpho-physiological and yield responses of black gram (*Vigna mungo* L.) and green gram (*Vigna radiata* L.) genotypes under drought at different growth stages. Research Journal of Recent Science. 5(2): 43-50.

Boyer, J.S. (1982). Plant productivity and environment. Science. 218: 443-448.

Collaku, A. (1994). Selection for yield and its components in a winter wheat population under different environmental conditions in Albania. Plant Breeding. 112(1): 40-46.

Dastane, N.G. (1972). Certain Common Formulae Used in Irrigation Pactices. In: A Practical Manual for Water Use Research in Agriculture: 30-31. Navbharath, Poona.

Gambao, A., Valmzuela, E.M. and Murlio, L. (1991). Morpho-physiological Variability and Yield Determinants for Drought Tolerance in Blackgram [*Vigna mungo* (L.) Hepper]. Journal of Plant Physiology. 137: 586-590.

Gurumurthy, S., Sarkar, B., Vanaja, M., Lakshmi, J., Yadav, S.K., and Maheswari, M. (2019). Morpho-physiological and biochemical changes in black gram [*Vigna mungo* (L.) Hepper] genotypes under drought stress at flowering stage. Acta Physiologiae Plantarum. 41(3): 1-14.

Manggoel, W., Uguru, M.I., Ndam, O.N. and Dasbak, M.A. (2012). Genetic variability, correlation and path coefficient analysis of some yield components of ten cowpea [*Vigna unguiculata* (L.) Walp] accessions. Journal of Plant Breeding and Crop Science. 4: 80-86

Noor, F., Ashraf, M. and Ghafoor, A. (2003). Path analysis and relationship among quantitative traits in chickpea (*Cicer arietinum* L.). Pakistan Journal Biology Science. 6: 551-555.

Riaz, R. and Chowdhry, M. (2003). Estimation of variation and heritability of some physio-morphic traits of wheat under drought conditions. Asian Jounal of Plant Science. 2(10): 748-755.

Rao, D., Naidu, T.C.M. and Ashoka Rani, Y. (2015). Effect of foliar nutrition on antioxidant enzymes, photosynthetic rate, dry matter production and yield of mung bean under receding soil moisture condition. International Journal of Pure Applied Bioscience. 3(1): 115-123.