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Morpho-physiological Indications of Moisture Stress Tolerance in Green Gram (*Vigna radiata* L.)

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ABSTRACT

Background: Moisture stress during crop growth has been identified as a significant challenge to sustained agricultural productivity. Screening of green gram germplasm for drought tolerance is a prerequisite for the development of tolerant varieties for improved production.

Methods: The study was aimed at evaluating the response of fifty genotypes of green gram to drought at the seedling stage using PEG 6000 in a laboratory setting and by withholding irrigation during the reproductive stage in pot culture experiment. The genotypes were assessed for seven different morpho-physiological traits from which seedling vigour indices, tolerance index, seedling dry weight tolerance index, root length tolerance index were also estimated in the lab study. The biochemical parameters namely proline content, total chlorophyll content and phenol content were also analysed in the field study.

Result: A wide variation among the genotypes with respect to all the morpho-physiological, biometrical and biochemical parameters was revealed in the study. The study revealed drought tolerance for the genotypes Andhra local, ML 1415, GM6 and Co 8. Most of the characters studied exhibited high heritability combined with high genetic advance indicating preponderance of additive gene action, suggesting selection to be an effective crop improvement strategy for development of drought tolerant varieties.

Key words: Moisture stress, Polyethylene glycol, Root traits, Tolerance index.

INTRODUCTION

Green gram (*Vigna radiata* L.) is a significant legume crop belonging to the *Fabaceae* family with chromosome number 2n =22. The crop possesses wide adaptability and demands minimal input resources. Its robust root system architecture actively participates in fixing atmospheric nitrogen (30-50 kg/ha) through symbiosis with *Rhizobium* bacteria, contributing significantly to soil fertility enhancement and sustainable agricultural yields. Additionally, as a rich source of vegetable proteins, micronutrients and antioxidants like flavonoids and phenolics, green gram serves various purposes including food, animal feed, fodder and gre0en manure (Choudhary *et al*., 2024).

Despite its economic importance, the productivity of green gram remains stagnant due to unpredictable weather patterns and various environmental stresses. Among these stresses, drought poses the greatest challenge to green gram cultivation, hindering its growth and development (Basu *et al*., 2019). Drought stress impacts various physiological processes crucial for growth and molecular functioning, resulting in reduced pod yield (51% to 85.5%) in pulses (Islam *et al*., 2024). The characters, plant height, seed weight, root architecture and crop yield are significantly reduced under the drought stress conditions in green gram and other legumes. Hence there is an utmost need to develop drought tolerant varieties to improve crop productivity especially under the changing climate. This study was conducted to screen drought tolerant green gram genotypes by assessing various biometrical, biochemical and genetic parameters.

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MATERIALS AND METHODS

The experiment was conducted at the Department of Genetics and Plant Breeding, College of Agriculture, Vellayani (8.5ºN, 76.9ºE and 29 m above mean sea level) during February to April 2024. Seed material representing 50 accessions of green gram collected from Indian Institute of Pulse Research (IIPR) Kanpur, Tamil Nadu Agricultural University (TNAU) Coimbatore, National Pulse Research Centre (NPRC) Vamban, Sardarkrushinagar Dantiwada Agricultural University (SDAU) Gujarat and National Bureau of Plant Genetic Resources (NBPGR) Vellanikkara, under Kerala Agricultural University (KAU) and various other local accessions were used in the study (Table 1).

Seeds were initially treated with 0.1% $HgCl_2$ for surface sterilization and residual chlorine was eliminated by thoroughly washing of seeds with distilled water. Seeds from each accession were raised by the roll paper towel method and subjected to different osmotic potentials using 5%, 10% and 20% PEG 6000 concentrations in the laboratory. The experiment was carried out during February 2024, using completely randomized design (CRD) with fifty green gram accessions in three replications. At 5% and 20% no significant variations were obtained, so the observations recorded at 10% only were included in further analysis. Observations on various morpho-physiological characters were examined in the seedling stage (10^{th} DAS) for drought tolerance *viz*., germination percentage [GP], root length [RL], shoot length [SL], root shoot ratio [RSR], seedling vigour index I [SVI I], vigour index II [SVI II] and seedling dry weight tolerance index [SDTI].

These fifty accessions of green gram were further raised in pots in completely randomized design (CRD) with three replications from March to April 2024. The meteorological data of the experimental site is given in Table 2. Moisture stress was imposed in the pot by withdrawing irrigation for 15 days during critical stages of growth *viz*., flowering and podding stage of the crop (reproductive stage). Soil moisture was also measured during this period by following gravimetric method (Reynolds, 1970). For comparison, a control with all genotypes was maintained under irrigated conditions. Twelve days after induction of droughtthe plants were pulled out and various morphological and biochemical parameters were recorded from the selected observational plants. The observations included root length (cm) [RL], shoot length (cm)[SL], seedling dry weight (g) [SDW], root dry weight (g) [RDW] and root diameter (cm) [RD] along with proline content (μ mol g^{-1}), total chlorophyll content (mg g^{-1}) and total phenol content (mg g^{-1}).

Biochemical analysis

The various relevant biochemical parameters namely proline content (μ mol g^{-1})(Bates *et al*., 1973), total chlorophyll content (mg g^{-1}) (Yoshida *et al*., 1971) and total phenol content (mg g^{-1}) (Sadasivam and Manickam, 1996) were estimated as per standard procedures.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) and various genetic parameters were worked out using GRAPES software, version 1.1.0 (Gopinath *et al*., 2020).

RESULTS AND DISCUSSION

Analysis of variance with respect to the various morpho-physiological parameters and the biochemical constituents revealed significant difference among the genotypes under study, which suggests ample scope for selection for improvement (Table 1). The morpho-physiological parameters in response to drought stress imposed by 10% PEG concentration revealed wide variation as illustrated in Table 2. The highest GP was obtained for Andhra local (100%) which was on par with VBN 3 (90%), ML1415 (80%), Co 8 (80%) and four other genotypes. With the imposition of stress, GP was reduced in all the genotypes. Reduction in GP due to increase in the PEG concentration were reported by Rakavi *et al*. (2022) in green gram and Eesha *et al*. (2023). The length and diameter of root of the seedlings were also drastically affected by PEG application. The accessions Co 8 (3.12 cm) was least affected which was on par with ML 1415 (2.64 cm), GM 6 (2.13 cm) andhra local (2.12 cm) and 23 other genotypes. The higher the RL greater will be the capacity of the plants to absorb more water and thus have the ability for resistance against drought. The RD ranged from 0.33 cm (C5-SML 668) to 0.76 cm (PLM 38). The genotype EC 396142 (0.71 cm) was on par with PLM 38. These findings were in accordance with Amarapalli (2022) in green gram and Mishra *et al*. (2024) in soybean. Reduced water potential imposed by PEG 6000 concentrations suppressed SL growth in all the genotypes. Corresponding observations were reported by Imtiaz *et al*. (2020) in green gram and Mishra *et al*. (2024) in soybean. The shoot length ranged from 9.42 cm (VBN 5)

The various indices pertaining to drought tolerance were estimated as follows.

Title index	Formula	Reference
Seedling dry weight tolerance index (SDWTI)	$\frac{\text{Dry weight of seedlings under stress}}{\text{Dry weight of seedlings under control}} \times 100$	Maiti *et al*., 1994
Germination drought tolerance index (GDTI)	$\frac{\text{Germination percentage under stress conditions}}{\text{Germination percentage under control}} \times 100$	Thabet *et al*., 2018
Root length tolerance index (RLTI)	$\frac{\text{Root length under stress conditions}}{\text{Root length under control}} \times 100$	Thabet *et al*., 2018
Shoot length drought tolerance index (SLDTI)	$\frac{\text{Shoot length under stress conditions}}{\text{Shoot length under control}} \times 100$	Thabet *et al*., 2018
Total dry weight drought tolerance index (TDWDTI)	$\frac{\text{Total dry weight under stress conditions}}{\text{Total dry weight under control}} \times 100$	Thabet *et al*., 2018
Seedling vigour index I (SV I)	[Germination percentage × Mean (Root length + Sηoot length)]	Abdul-Baki and Anderson (1973)
Seedling vigour index II (SV II)	(Germination percentage × Seedling dry weight)	Abdul-Baki and Anderson (1973)

to 55.00 cm (EC 165632). Taller genotypes are comparatively more sensitive to drought stress compared to shorter ones.

Under stress, GM 9 (8.53) recorded highest RSR which is on par with GM 9 (8.53) and ten other genotypes. A significant decrease in RSR was observed under moisture stress condition which was in accordance with the findings of Himaja *et al*. (2023). The RDW ranged from 0.10g (C2 IPM2 14-2) to 2.76 g (Co 8) and TPDW ranges from 0.10 g (IC 548369) to 6.26 g (VBN 3). The SdDW was maximum for IPM 031 (42.65 mg) which is on par with GM 6 (37.50 mg) and lowest was recorded by IC 548369 (0.00 mg). Root and seedling dry weight showed a significant increase during moisture stress conditions (Imtiaz *et al*., 2020).

Estimation of various tolerance indices will enable us to understand the impact of stress on the various genotypes. In the present study, vigour index was suppressed with increasing PEG concentration which was also reported by Bhujel *et al*. (2024) in green gram. Among the genotypes andhra local (408.00) and GM 6 (2250.00) recorded the highest vigour index I and II respectively under the stress condition (Table 3). These indexes can be used us an important tool to identify genotypes that are superior in drought prone areas.

The genotypes also showed significant variations with respect to biochemical parameters like proline content, total chlorophyll content and total phenol content with the imposition of drought stress (Table 4). An increase in proline content was found in all the genotypes (Islam *et al*., 2023). The increased levels of proline in tissues can be used as an indicator of the degree of water deficit and can also as a criterion for screening drought tolerant varieties (Kabbadj *et al.,* 2017). The genotype ML 1415 (35.59μ $molg^{-1}$), IC 148530 (34.12 μ $molg^{-1}$) and C5 SML 668 (31.84μ $molg^{-1}$) was on par with IC 395518.

The chlorophyll content decreased in all the genotypes and the reduction may be due to inhibition of chlorophyll biosynthesis and photo-oxidation. Genotypes exhibiting enhanced drought tolerance due to chlorophyll stability was reported by Islam *et al*. (2023) in green gram. Total phenol content ranged from 0.04 mgg^{-1} (VBN 3) to 9.47 mgg^{-1} (IC 607183). Drought stress increased the total phenol content in leaves of majority of the genotypes as compared

Table 1: ANOVA of morpho-physiological and biochemical parameters under moisture stress.

Characters	MSS of source	MSS of error	F
Germination percentage (%)	1495.837	112.000	13.356*
Reduction in germination percentage (%)	1478.629	132.972	11.120*
Seedling root length (cm)	1.759	0.448	3.930*
Reduction in seedling root length (%)	658.160	139.619	4.714*
Seedling shoot length (cm)	0.547	0.169	3.230*
Reduction in seedling shoot length (cm)	30.031	8.155	3.683*
Seedling length (cm)	3.686	0.849	4.339*
Reduction in seedling length (cm)	88.698	22.336	3.971*
Seedling dry weight (mg)	150.639	15.910	9.468*
Reduction in dry weight of seedling (mg)	3952.997	116.292	33.992*
Root-shoot ratio	8.220	3.952	2.080*
Reduction in root-shoot ratio	1111988.790	366306.852	3.036*
Root length (cm)	243.739	21.423	11.378*
Shoot length (cm)	635.317	4.383	144.955*
Root diameter (cm)	0.026	0.002	15.738*
Root dry weight (g)	0.467	0.015	32.022*
Total plant dry weight (g)	5.022	0.350	14.369*
Seedling vigour index 1	23821.974	1159.297	20.548*
Reduction in vigour index 1	52.348	3.140	16.674*
Seedling vigour index 2	411122.393	38563.729	10.661*
Reduction in vigour index 2	1451.742	175.902	8.253*
Seedling dry weight tolerance index	0.394	0.010	40.519*
Total plant dry weight tolerance index	8309.59	387.49	21.445*
Root length tolerance index	14272.749	569.439	25.065*
Shoot length tolerance index	1036.222	6.227	166.406*
Germination tolerance index	1890.681	143.234	13.200*
Proline content (μ $molg^{-1}$)	348.634	7.685	45.365*
Total chlorophyll content (mg g^{-1})	2.128	0.482	4.417*
Phenol content (mg g^{-1})	11.204	0.403	27.783*

*Since the P-value in ANOVA table is < 0.05,there is a significant difference between atleast a pair of treatments.

Table 2: Morpho-physiological and biometric characters in greengram germplasm under moisture stress.

Genotypes	GP (%)	SRL (cm)	SSL (cm)	SI (cm)	SDW (mg)	SRSR	RL (cm)	SL (cm)	RD (cm)	RDW (g)	TPDW (g)
Andhra local	100.00	2.12	1.96	4.08	12.24	1.08	30.16	10.00	0.46	0.40	2.30
TM 96	60.00	3.02	0.65	3.67	13.86	5.08	27.59	34.78	0.44	0.25	0.17
IPM 205 7	20.00	1.60	0.90	2.50	7.21	0.89	18.64	22.74	0.43	0.33	2.75
Thiruvalla local	60.00	1.93	1.70	3.63	16.58	1.16	29.67	8.48	0.49	0.32	3.33
EC 396143	20.00	1.10	0.17	1.27	27.36	6.76	20.37	10.33	0.54	0.35	2.17
IPM 031	20.00	0.25	0.00	0.25	42.65	0.00	25.69	35.77	0.37	0.51	1.13
C4 PDM 139	40.00	1.31	0.52	1.83	8.90	2.50	25.97	11.93	0.45	0.95	2.69
ML 1415	80.00	2.65	1.26	3.91	4.17	2.11	34.37	5.20	0.38	0.32	3.76
Co GG 912	20.00	2.75	1.25	4.00	11.00	2.38	7.31	34.67	0.37	0.15	1.31
Co 8	80.00	3.13	1.33	4.46	6.74	2.87	32.33	12.36	0.42	2.76	3.00
IC 395518	40.00	1.50	1.44	2.94	4.80	1.21	43.00	5.54	0.43	0.45	3.29
GM 4	40.00	2.19	0.42	2.61	5.40	5.21	26.54	28.11	0.34	0.62	2.35
VBN 4	80.00	2.35	1.22	3.57	13.76	2.36	13.25	44.33	0.39	0.22	3.40
IPM 312 20	60.00	1.25	0.19	1.44	5.66	7.81	19.66	32.46	0.43	0.27	2.21
IC 148530	70.00	2.00	0.80	2.80	4.20	2.49	48.40	6.58	0.54	0.66	3.40
Co 9	80.00	2.24	0.98	3.22	9.80	2.34	15.90	38.67	0.49	0.40	0.27
VBN 2	60.00	2.56	0.76	3.33	10.74	3.36	12.98	48.22	0.42	0.35	5.41
VBN 3	90.00	2.82	0.83	3.65	5.04	3.97	9.87	45.33	0.44	0.32	6.26
PLM 963	70.00	2.06	0.81	2.87	7.79	2.83	15.30	37.33	0.41	0.30	3.78
VBN 1	50.00	2.10	1.32	3.42	9.84	1.65	18.58	4.69	0.48	0.28	2.61
IC 553601	20.00	0.20	0.05	0.25	9.51	2.00	28.77	37.48	0.41	0.61	3.55
EC 398884	70.00	0.46	0.10	0.56	19.02	4.64	32.19	29.33	0.46	0.76	1.60
C5 SML 668	60.00	1.98	0.25	2.23	7.52	8.18	28.13	8.65	0.33	0.37	2.77
C2 IPM2 14 – 1	20.00	0.40	0.15	0.55	3.42	1.33	16.76	39.35	0.39	0.32	2.94
GM 6	60.00	2.13	1.26	3.39	37.50	1.90	16.76	39.35	0.45	0.62	2.94
GM 7	20.00	2.40	1.75	4.15	7.76	1.45	20.77	27.16	0.45	0.54	2.75
GM 8	70.00	3.03	1.34	4.37	10.30	3.14	23.62	39.30	0.45	0.42	2.27
IC 148531	50.00	1.00	0.25	1.25	14.70	3.78	24.73	24.83	0.45	0.51	0.85
IC 597670	80.00	2.34	1.09	3.43	8.12	2.18	13.91	36.79	0.40	0.11	2.94
IC 607183	20.00	0.35	0.15	0.50	16.64	1.17	9.59	39.22	0.37	0.10	1.08
VBN 5	80.00	1.88	0.62	2.50	9.66	4.83	28.33	9.42	0.61	0.58	3.19
C2 IPM2 14 -2	60.00	0.26	0.10	0.36	10.42	2.57	6.85	30.55	0.35	0.10	1.66
Kayamkulam local	20.00	1.65	0.82	2.47	19.42	2.91	23.48	6.50	0.52	0.29	2.62
GM 9	40.00	2.72	0.32	3.04	15.58	8.53	22.24	33.31	0.44	0.65	2.62
Trivandrum local	60.00	2.12	1.30	3.42	25.06	1.64	21.41	35.49	0.37	0.75	2.39
Kozhikode local	60.00	1.42	0.43	1.84	12.18	3.33	23.22	7.33	0.63	0.22	0.67
IC 148516	80.00	2.01	0.39	2.40	15.50	5.05	17.40	27.50	0.45	0.18	0.96

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EC 396142	20.00	0.10	0.05	0.15	3.05	1.00	20.37	10.33	0.72	0.47	2.17
HDM 12	20.00	0.60	0.35	0.95	2.07	0.86	32.11	38.55	0.35	0.37	0.78
EC 314302	50.00	1.90	0.51	2.41	18.00	3.89	13.91	36.79	0.38	0.19	2.94
IC 520034	20.00	0.10	0.05	0.15	3.02	1.00	12.02	28.37	0.35	0.23	2.08
EC 165632	60.00	0.65	0.42	1.07	23.90	2.93	14.53	55.00	0.43	0.41	5.12
PLM 38	30.00	2.75	0.58	3.33	18.02	5.88	14.53	55.00	0.76	0.39	5.12
PLM 794	20.00	0.60	0.30	0.90	15.2	1.00	21.92	4.33	0.60	0.46	1.19
IC 548369	0.00	0.00	0.00	0.00	0.000	0.00	32.95	35.38	0.36	1.13	0.10
IC 606545	20.00	0.60	0.30	0.90	16.30	1.00	19.90	15.96	0.47	0.41	1.12
IC 418452	30.00	3.00	1.08	4.08	10.21	3.14	32.93	8.27	0.61	0.56	2.67
EC 272458	20.00	0.55	0.15	0.70	12.26	3.50	11.61	49.33	0.38	0.32	3.17
IC 488962	20.00	1.50	0.70	2.20	27.98	2.17	35.79	26.17	0.38	0.84	4.03
C1 IPM02 3	30.00	1.55	0.31	1.86	12.26	5.04	21.79	34.16	0.38	0.40	3.16
Mean	45.20	1.62	0.67	2.29	12.54	2.96	22.84	26.27	0.44	0.47	2.48
SE(d)	11.28	0.66	0.41	0.92	3.98	1.98	3.77	1.70	0.03	0.09	0.48
CD (5%)	21.25	1.34	0.82	1.85	8.01	3.90	7.49	3.39	0.06	0.19	0.95
CV	24.97	41.21	61.13	40.13	31.79	67.11	20.26	7.96	9.23	25.6	23.78

GP –Germination percentage (%); SI - Seedling length (cm); SRL – Seedling root length (cm); RSR - Root: shoot ratio; SSL – Seedling shoot length (cm); RL – Root length (cm); RD – Root diameter (cm); SL – Shoot length (cm); RDW – Root dry weight (g); TPDW – Total plant dry weight (g); SDW – Seedling dry weight (g).

Table 3: Drought tolerance indices in greengram germplasm under moisture stress.

Genotypes	SVI I	SVI II	SDWDTI	TPDWDTI	RLDTI	SLDTI	GDTI
Andhra local	408.00	1224.00	0.16	40.96	227.40	82.12	100.00
TM 96	220.45	831.60	0.36	236.68	376.54	75.93	40.00
IPM 205 7	50.00	134.80	0.19	71.92	126.39	115.18	20.00
Thiruvalla local	217.50	994.80	0.67	123.67	145.32	93.04	60.00
EC 396143	25.30	547.20	0.59	98.67	154.00	90.59	10.00
IPM 031	5.00	853.00	0.54	85.23	168.75	100.18	46.67
C4 PDM 139	73.13	356.00	0.19	40.29	157.33	88.10	40.00
ML 1415	312.40	334.00	0.16	154.78	207.93	75.75	73.33
Co GG 912	80.00	220.00	0.36	21.39	78.20	78.79	20.00
Co 8	357.00	539.20	0.14	110.00	150.29	68.24	80.00
IC 395518	117.60	192.00	0.12	46.73	190.70	74.17	40.00
GM 4	104.40	216.00	0.10	63.78	118.59	64.06	46.67
VBN 4	285.80	1100.80	0.53	60.81	138.07	73.88	26.67
IPM 312 20	71.20	339.60	0.25	58.60	238.51	107.00	20.00
IC 148530	192.00	294.00	0.09	95.21	343.03	112.10	70.00
Co 9	257.60	784.00	0.19	31.99	96.78	60.03	20.00
VBN 2	199.50	644.40	0.22	76.12	124.24	121.54	26.67
VBN 3	324.00	454.05	0.16	300.80	61.26	116.24	20.00
PLM 963	186.32	545.72	0.23	51.86	132.64	86.82	20.00
VBN 1	170.33	492.00	0.3	115.31	200.42	83.44	26.67
IC 553601	5.00	156.40	0.24	144.79	236.22	103.52	80.00
EC 398884	37.10	1331.40	0.38	46.86	209.37	71.46	86.67
C5 SML 668	133.90	451.20	0.24	41.33	250.72	74.52	80.00
C2 IPM2 14 -1	11.00	69.00	0.07	33.99	70.40	60.55	20.00
GM 6	186.67	2250.00	3.12	61.71	154.67	85.65	26.67
GM 7	83.00	155.20	0.27	59.15	109.59	105.40	53.33
GM 8	293.10	721.00	0.28	61.84	197.00	88.31	53.33
IC 148531	51.53	735.00	0.90	58.42	201.54	75.93	33.33
IC 597670	274.00	649.60	0.13	30.08	67.65	121.15	26.67
IC 607183	7.00	166.40	0.34	80.68	57.16	120.54	20.00
VBN 5	200.00	772.80	0.26	99.81	157.79	71.86	80.00
C2 IPM2 14-2	15.40	625.20	0.33	53.12	156.44	120.54	20.00
Kayamkulam local	49.40	388.40	0.59	133.34	155.55	122.36	53.33
GM 9	121.47	623.20	0.47	81.01	170.87	83.22	53.33
Trivandrum local	204.90	1503.60	0.48	137.85	172.18	94.84	66.67
Kozhikode local	110.40	730.80	0.39	62.51	216.79	62.78	60.00
IC 148516	192.13	1240.00	0.44	38.91	107.10	75.93	26.67
EC 396142	2.00	61.00	0.08	67.66	265.63	122.36	16.67
HDM 12	19.00	41.40	0.06	49.37	266.67	85.12	73.33
EC 314302	112.50	900.00	0.19	50.21	121.02	93.04	26.67
IC 520034	2.00	0.00	0.07	19.69	134.69	90.27	20.00
EC 165632	64.10	1434.00	0.31	97.47	104.02	121.15	26.67
PLM 38	91.00	540.60	0.62	124.03	138.48	82.18	30.00
PLM 794	12.00	152.30	0.30	21.75	146.67	64.44	10.00
IC 548369	0.00	0.00	0.00	61.46	233.79	82.62	93.33
IC 606545	12.00	326.00	0.29	76.66	113.33	110.18	60.00
IC 418452	119.00	306.30	0.70	76.04	162.57	82.18	60.00
EC 272458	11.00	245.32	0.20	82.95	126.67	78.79	20.00
IC 488962	30.00	559.60	0.65	127.37	290.67	110.31	80.00
Mean	123.19	572.01	0.37	80.14	168.17	87.94	44.06
SE(d)	34.04	196.37	0.09	16.12	19.24	1.27	9.73
CD (5%)	68.38	394.43	0.19	31.98	38.17	2.52	19.30
CV	27.63	34.33	26.59	24.63	14.04	1.77	27.04
C1 IPM02 3	51.60	367.80	0.33	42.57	176.92	80.17	40.00
Mean	123.19	572.01	0.37	80.14	168.17	87.94	44.06
SE(d)	34.04	196.37	0.09	16.12	19.24	1.27	9.73
CD (5%)	68.38	394.43	0.19	31.98	38.17	2.52	19.30
CV	27.63	34.33	26.59	24.63	14.04	1.77	27.04

Table 4: Biochemical parameters in greengram germplasm under moisture stress.

Genotypes	Proline content (μ molg^{-1})	Total chlorophyll content (mg g^{-1})	Phenol content (mg g^{-1})
Andhra local	15.11	0.07	3.40
TM 96	0.85	0.41	3.35
IPM 205 7	10.90	0.53	1.80
Thiruvalla local	30.29	0.81	2.56
EC 396143	15.44	0.14	2.30
IPM 031	6.89	0.69	1.89
C4 PDM 139	26.90	1.08	2.65
ML 1415	35.60	0.97	5.18
Co GG 912	23.98	2.51	6.27
Co 8	28.45	0.87	2.79
IC 395518	37.61	0.14	3.83
GM 4	9.06	0.44	1.46
VBN 4	4.24	2.58	1.00
IPM 312 20	16.86	1.21	1.82
IC 148530	34.12	1.41	2.9
Co 9	0.65	0.68	0.54
VBN 2	5.05	0.75	5.11
VBN 3	0.26	0.40	0.04
PLM 963	7.68	1.23	3.72
VBN 1	23.22	0.60	2.20
IC 553601	18.95	1.94	2.28
EC 398884	3.64	0.63	3.39
C5 SML 668	31.84	1.68	5.17
C2 IPM2 14 -1	5.28	3.07	1.36
GM 6	7.91	0.52	1.14
GM 7	15.2	0.47	2.18
GM 8	6.56	1.16	1.30
IC 148531	9.98	2.74	2.35
IC 597670	0.85	0.24	0.22
IC 607183	8.40	0.28	9.47
VBN 5	29.00	0.93	2.31
C2 IPM2 14 -2	10.60	1.06	8.24
Kayamkulam local	25.22	0.90	2.92
GM 9	13.16	0.52	1.18
Trivandrum local	14.26	1.99	3.78
Kozhikode local	5.36	2.68	1.86
IC 148516	7.91	3.31	1.48
EC 396142	15.44	0.14	2.30
HDM 12	1.98	0.46	3.43
EC 314302	24.28	1.26	1.93
IC 520034	2.49	0.94	0.13
EC 165632	19.56	1.64	2.45
PLM 38	23.00	1.86	2.68
PLM 794	2.59	2.73	2.13
IC 548369	0.30	1.26	2.69
IC 606545	14.20	1.99	1.94
IC 418452	24.70	0.36	2.81
EC 272458	2.75	0.29	7.39
IC 488962	2.83	0.43	1.28
C1 IPM02 3	6.80	0.95	1.36
Mean	13.59	1.13	2.76
SE(d)	2.26	0.56	0.51
CD (5%)	4.49	1.12	1.02
CV	20.39	60.99	22.94

Table 5: Genetic variability parameters of moisture stress tolerance characters in greengram.

Character	Mean	PCV (%)	GCV (%)	H^2(%)	GAM (5%)
Germination percentage (%)	45.20	63.270	58.132	84.40	110.025
Seedling root length (cm)	1.62	64.717	49.879	60.40	79.193
Seedling shoot length (cm)	0.67	88.886	64.583	52.80	96.667
Seedling length (cm)	2.29	65.575	51.866	62.60	84.506
Seedling dry weight (g)	0.12	72.745	65.428	80.90	121.225
Root: Shoot ratio	2.96	83.287	49.318	35.10	60.160
Root length (cm)	22.84	42.787	37.685	77.60	68.375
Shoot length (cm)	26.27	55.776	55.204	98.00	112.553
Root diameter (cm)	0.44	22.318	19.962	80.00	36.780
Root dry weight (g)	0.47	86.564	82.552	90.90	162.175
Total plant dry weight	2.48	55.552	50.197	81.60	93.438
Proline content (μ $molg^{-1}$)	13.59	81.049	78.441	93.70	156.387
Total chlorophyll (mg g^{-1})	1.13	89.195	65.078	53.20	97.813
Phenol content (mg g^{-1})	2.76	72.277	68.453	89.90	133.903

with the well watered control. This was in conformity with the results of Ashraf and Siddiqi (2024) in sunflower.

The phenotypic and genotypic coefficient of variation for the characters GP, SdL, SdRL, SdSL, SdDW, RSR, SVI I and II, SDWTI, RL, SL, RD, TPDW, RDW, proline content, total chlorophyll content and phenol content were estimated to be high indicating a high variation among the genotypes (Table 5). Estimates of phenotypic coefficient of variations (PCV) were higher than genotypic coefficient of variations (GCV) for all the characters under study which indicated some environmental influence on these characters. High values of GCV and PCV were also observed for drought tolerance traits such as chlorophyll content (spad chlorophyll meter reading), leaf water potential, proline content, relative water content and specific leaf area by Kanavi *et al.* (2020). High heritability and genetic advance estimates were recorded for most of the characters in the studyindicating the preponderance of additive gene action suggesting selection strategies can improve these characters (Kanavi *et al.,* 2020 and Bordoloi *et al.,* 2023).

CONCLUSION

Extensive variation with respect to the drought tolerant parameters were revealed from the study which suggests ample scope for improvement in green gram. The genetic parameters namely PCV, GCV, heritability and genetic advance also suggested preponderance of additive gene action for most of the parameters evaluated namely, germination percentage, seedling shoot traits, seedling root traits, tolerance indices, proline content, total chlorophyll content and phenol content. Considering both the experiments the genotypes Andhra local, ML 1415, Co 8 and GM 6 can be considered as source of moisture stress tolerance. The superiors genotypes identified in the study can be recommended for cultivation as well as may be used as donor parents in future breeding programmes.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarilyrepresent the views of their affiliated institutions. The authors are responsible for the accuracy andcompleteness of the information provided, but do not accept any liability for any direct or indirect lossesresulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal careand handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. Nofunding or sponsorship influenced the design of the study, data collection, analysis, decision to publish,or preparation of the manuscript.

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