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Correlation coefficient studies among physiological and yield attributing traits in germplasm accessions of green gram [*Vigna radiata* (L.)] under drought condition

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Abstract
Two hundred germplasm accessions of Green gram [*Vigna radiate* (L.) Wilczek] were screened for drought tolerance using augmented design. Augmented ANOVA revealed highly significant mean squares attributable to germplasm accessions for all the traits. Mean squares attributable to 'Genotypes *vs* check entries' were significant for all traits except seed per pod and relative water content. The correlation coefficient analysis revealed that out of 17 independent variables studied, 15 variables showed positive correlation with dependent variable yield. Two variables namely days to 50 *per cent* flowering and days to maturity did not show positive correlation with yield. Among the independent variables, pods per cluster had highest positive correlation with seed yield per plant (0.84) followed by pods per cluster (0.77) clusters per plant (0.71), plant height (0.68), proline content (0.63), spad chlorophyll meter reading (0.62), leaf water potential (0.61), harvest index and seeds per pod (0.60).

Keywords: Green gram germplasm, correlation coefficient, drought tolerance, quantitative and physiological traits

Introduction

Green gram, alternatively known as mung bean, or mugda is the third most important pulse crop of India after chickpea and pigeon pea. It is a fast-growing grain legume belonging to the family Fabaceae. Being a short-duration legume, it is an ideal legume for catch cropping, intercropping, and relay cropping (Pooja *et al.*, 2019) [1]. Mung bean has the ability to fix nitrogen via symbiosis with nitrogen-fixing Rhizobium bacterium (Allito *et al.*, 2015) [2]. Pulse crops are important valuable grain legumes that are widely used as food, fodder and feed. Pulses are important constituents of the Indian diet, green gram has excellent and easily digestible source of protein for humans and is said to be an alternate to animal protein such as meat, ultimately supporting food security. The mature seeds are rich in nutrients including carbohydrates, protein, fibers, minerals, antioxidants like flavonoids (Quercetin-3-Oglucoside), and phenolics. Despite being an economically important pulse crop, overall production of mung bean in India is low due to abiotic and biotic stresses (Bangar *et al.*, 2018) [3].

Among abiotic stresses, drought stress is undoubtedly one of the most devastating environmental stresses especially in crop like green gram whose cultivation is mostly confined to marginal lands, low fertile soils and in rainfed conditions. Drought is a meteorological term and is commonly defined as a period without soil moisture availability for crop growth and development. Drought is a multidimensional complex stress, simultaneously disturbing the metabolic, physiological, morphological, biochemical, and molecular states which has direct impact on the growth, development and productivity of the crop (Basu *et al.*, 2016) [4]. The agricultural crops are frequently exposed to drought situations and this stress is aggravating worldwide as drought-stressed areas are expanding rapidly due to uneven rainfall, limited water sources, and other rapid and drastic changes in global environmental conditions (Fahad *et al.*, 2017) [5].

To improve stress tolerance in agricultural crops, many studies have been conducted to identify tolerant genotypes against abiotic stresses for domesticated accessions as reported by Munns and James (2003) [6], Torres *et al.* (2013) [7], Sardouie-Nasab *et al.* (2014) [8] and Monkham *et al.* (2015) [9]. Several biochemical and morpho-physiological parameters have been established for drought stress tolerance assessment in plants based on proline accumulation, high relative water content, leaf area index, yield components, antioxidant enzymatic activities and PEG mediation and the same has been reported by Mafakheri *et al.* (2010) [10], Almeselmani *et al.* (2011) [11], Ranawake *et al.* (2012) [12], Alderfasi *et al.* (2017) [13] and Swathi *et al.* (2017) [14]. Therefore designing an effective phenotypic screening strategy for crop improvement and a better understanding of the responses of mung bean varieties under different drought stress conditions is essential (Abenavoli *et al.*, 20161) [15]. Assessment of variability parameters and their correlation under drought conditions would be helpful in selecting diverse valuable varieties with defined growth strategies, which may be useful in breeding programs focused on drought tolerance as referred by Abraha *et al.* (2015) [16], Mishra and Panda (2017) [17] and Tiwari *et al.* (2018) [18].

Material and Methods

The study material consisted of 200 germplasm accessions collected from different research institutions / organizations representing different agro-climatic zones. List of germplasm accessions used in the study with their source is given in table No1.

Layout of the experiment

The experiment was conducted in an Augmented Randomized Complete Block Design with 200 germplasm accessions and 5 check varieties. As per the augmented RCBD requirement, the check entries were replicated twice randomly in each of the block. There were 5 blocks, each block had 5 plots of size 3x3 m^2 thus each block size was 15 m^2. The gross area of experimental plot was 75 m^2. The row spacing was 30 cm and inter plant distance was 10 cm. The experiment was conducted during *summer* 2015. Recommended crop production practices were followed during the crop growth period to raise healthy crop.

Imposing drought condition

Drought condition was imposed by withholding irrigation 25 days after sowing. The same practice of inducing drought is reported by Baroowa and Gogoi (2015) [19] and Pooja *et al.* (2019) [1]. Since the experiment was conducted during *summer* season, there were no unpredicted rains during the entire cropping period hence the drought condition was effectively imposed. The rainfall data of experimental site during the cropping period is given in table2.

Plant sampling and data collection

Observations were recorded on five randomly chosen competitive plants from each germplasm accession for all the characters except days to 50 *per cent* flowering and days to maturity, which were recorded on plot basis. The values of five competitive plants were averaged and expressed as mean of the respective characters. The observations were taken on the traits like; Days to 50% flowering, Days to maturity, Plant height (cm), Clusters per plant, Pods per cluster, Pods per plant, Pod length (cm), Seeds per pod, test weight, Threshing %, Harvest index (%), SCMR (SPAD Chlorophyll meter reading), Leaf water potential(Mpa), Proline content ($\mu g\ g^{-1}$), Relative water content, Specific leaf area and Seed yield per plant.

Table 1: List of germplasm accessions used in the study and their source

S. No.	Germplasm	Location	Sl. No.	Germplasm	Location
1	KM13-16	ARS, Bidar	29	VGG10-010	TNAU, Coimbatore
2	KM13-19	ARS, Bidar	30	VGG04-011	TNAU, Coimbatore
3	KM13-39	ARS, Bidar	31	VGG04-007	TNAU, Coimbatore
4	GG13-7	ARS, Bidar	32	COGG-93	TNAU, Coimbatore
5	GG13-6	ARS, Bidar	33	VBNGG-2	TNAU, Coimbatore
6	KM13-44	ARS, Bidar	34	TARM-2013	TNAU, Coimbatore
7	GG13-10	ARS, Bidar	35	VGG04-005	TNAU, Coimbatore
8	SML-668	ARS, Bidar	36	COGG-920	TNAU, Coimbatore
9	KM13-9	ARS, Bidar	37	VGG07-003	TNAU, Coimbatore
10	IPM99-125	ARS, Bidar	38	VGG10-002	TNAU, Coimbatore
11	LGG-596	RARS, Guntur	39	VGG-112	TNAU, Coimbatore
12	LGG-572	RARS, Guntur	40	IC-92048	NBPGR, Akola
13	LGG-450	RARS, Guntur	41	AKL-103	NBPGR, Akola
14	LGG-583	RARS, Guntur	42	AKL-39	NBPGR, Akola
15	LGG-590	RARS, Guntur	43	AKL-106	NBPGR, Akola
16	LGG-588	RARS, Guntur	44	AKL-225	NBPGR, Akola
17	LGG-589	RARS, Guntur	45	AKL-95	NBPGR, Akola
18	LGG-579	RARS, Guntur	46	AKL-194	NBPGR, Akola
19	LGG-562	RARS, Guntur	47	AKL-212	NBPGR, Akola
20	LGG-582	RARS, Guntur	48	AKL-195	NBPGR, Akola
21	LGG-585	RARS, Guntur	49	AKL-211	NBPGR, Akola
22	AKL-170	NBPGR, Akola	50	KM13-11	ARS, Bidar
23	PLM-110	UAS, Bangalore	51	KM13-30	ARS, Bidar
24	LGG-577	RARS, Guntur	52	KM13-45	ARS, Bidar
25	IC-436624	IIPR, Kanpur	53	KM13-18	ARS, Bidar
26	IC-436723	IIPR, Kanpur	54	KM13-5	ARS, Bidar
27	IC-413316	IIPR, Kanpur	55	KM13-02	ARS, Bidar
28	IC-436746	IIPR, Kanpur	56	KM13-37	ARS, Bidar
57	KM13-23	ARS, Bidar	98	LGG-592	NBPGR, Akola
58	KM13-55	ARS, Bidar	99	LGG-555	NBPGR, Akola
59	KM13-12	ARS, Bidar	100	LGG-564	NBPGR, Akola
60	GG13-9	ARS, Bidar	101	LGG-460	RARS, Guntur
61	KM13-49	ARS, Bidar	102	LGG-595	RARS, Guntur
62	GG13-4	ARS, Bidar	103	LGG-566	RARS, Guntur
63	GG13-54	ARS, Bidar	104	IC-553514	IIPR, Kanpur
64	KM13-20	ARS, Bidar	105	IC-413319	IIPR, Kanpur

65	GG13-5	ARS, Bidar	106	IC-436542	IIPR, Kanpur
66	Chinamung	ARS, Bidar	107	IC-546493	IIPR, Kanpur
67	GG13-2	ARS, Bidar	108	IC-436594	IIPR, Kanpur
68	KM13-26	ARS, Bidar	109	IC-436630	IIPR, Kanpur
69	KM13-47	ARS, Bidar	110	IC-436668	IIPR, Kanpur
70	KM13-41	ARS, Bidar	111	IC-436555	IIPR, Kanpur
71	KM13-11	ARS, Bidar	112	IC-413314	IIPR, Kanpur
72	KM13-42	ARS, Bidar	113	AKL-20	NBPGR, Akola
73	GG13-11	ARS, Bidar	114	AKL-89	NBPGR, Akola
74	GG13-8	ARS, Bidar	115	AKL-228	NBPGR, Akola
75	GG13-12	ARS, Bidar	116	AKL-184	NBPGR, Akola
76	KM13-48	ARS, Bidar	117	AKL-182	NBPGR, Akola
77	IPM2-3	ARS, Bidar	118	AKL-230	NBPGR, Akola
78	IPM2-14	ARS, Bidar	119	AKL-229	NBPGR, Akola
79	PDM-139	ARS, Bidar	120	AKL-86	NBPGR, Akola
80	LGG-580	RARS, Guntur	121	IC-436646	IIPR, Kanpur
81	PM-112	TNAU, Coimbatore	122	IC-343964	IIPR, Kanpur
82	LGG-578	NBPGR, Akola	123	IC-436528	IIPR, Kanpur
83	LGG-563	NBPGR, Akola	124	IC-436723	IIPR, Kanpur
84	LGG-594	NBPGR, Akola	125	IC-546491	IIPR, Kanpur
85	TM-96-2	NBPGR, Akola	126	IC-546481	IIPR, Kanpur
86	LGG-593	NBPGR, Akola	127	IC-398988	IIPR, Kanpur
87	LGG-591	NBPGR, Akola	128	VGG10-005	TNAU, Coimbatore
88	PM-115	NBPGR, Akola	129	VBN-223	TNAU, Coimbatore
89	LGG-587	NBPGR, Akola	130	COGG-912	TNAU, Coimbatore
90	PM-113	NBPGR, Akola	131	VBN(G9)-3	TNAU, Coimbatore
91	LGG-586	NBPGR, Akola	132	ML-1165	TNAU, Coimbatore
92	IC-436775	NBPGR, Akola	133	VGG04-025	TNAU, Coimbatore
93	IC-413311	NBPGR, Akola	134	VGG04-004	TNAU, Coimbatore
94	IC-398984	NBPGR, Akola	135	VGG04-149	TNAU, Coimbatore
95	IC-436767	NBPGR, Akola	136	COGG-954	TNAU, Coimbatore
96	IC-436573	NBPGR, Akola	137	VGG08-002	TNAU, Coimbatore
97	LGG-584	NBPGR, Akola	138	VBN-1	TNAU, Coimbatore
139	VGG-119	TNAU, Coimbatore	179	AKL-84	NBPGR, Akola
140	VC3890-A	TNAU, Coimbatore	180	AKL-82	NBPGR, Akola
141	DGGV-4	UAS, Raichur	181	AKL-97	NBPGR, Akola
142	KPS-1	UAS, Raichur	182	AKL-226	NBPGR, Akola
143	CGG-973	UAS, Raichur	183	AKL-24	NBPGR, Akola
144	CN9-5	UAS, Raichur	184	AKL-174	NBPGR, Akola
145	KPS-2	UAS, Raichur	185	AKL-161	NBPGR, Akola
146	VC-6173	UAS, Raichur	186	AKL-180	NBPGR, Akola
147	VC-6368	UAS, Raichur	187	AKL-222	NBPGR, Akola
148	CO-6	UAS, Raichur	188	AKL-187	NBPGR, Akola
149	Harsha	UAS, Raichur	189	AKL-216	NBPGR, Akola
150	PLM-92	UAS, Bangalore	190	AKL-29	NBPGR, Akola
151	MH-709	UAS, Raichur	191	AKL-90	NBPGR, Akola
152	LGG-460	RARS, Guntur	192	AKL-227	NBPGR, Akola
153	KGS-5	UAS, Raichur	193	AKL-200	NBPGR, Akola
154	Barimung-4	UAS, Raichur	194	AKL-92	NBPGR, Akola
155	AKL-189	NBPGR, Akola	195	AKL-183	NBPGR, Akola
156	AKL-168	NBPGR, Akola	196	AKL-176	NBPGR, Akola
157	AKL-218	NBPGR, Akola	197	AKL-191	NBPGR, Akola
158	AKL-179	NBPGR, Akola	198	AKL-165	NBPGR, Akola
159	AKL-185	NBPGR, Akola	199	AKL-164	NBPGR, Akola
160	AKL-163	NBPGR, Akola	200	AKL-192	NBPGR, Akola
161	COGG-912	TNAU, Coimbatore			
162	IC-73451	NBPGR, Akola			
163	IC-105690	NBPGR, Akola			
164	IC-73534	NBPGR, Akola			
165	IC-73412	NBPGR, Akola			
166	IC-39605	NBPGR, Akola			
167	IC-73472	NBPGR, Akola			
168	IC-92053	NBPGR, Akola			
169	IC-73779	NBPGR, Akola			
170	IC-73462	NBPGR, Akola			
171	IC-118992	NBPGR, Akola			
172	IC-53783	NBPGR, Akola			
173	IC-73456	NBPGR, Akola			
174	IC-73458	NBPGR, Akola			

175	AKL-105	NBPGR, Akola			
176	AKL-213	NBPGR, Akola			
177	AKL-169	NBPGR, Akola			
178	AKL-220	NBPGR, Akola			

Table 2: Meteorological data of experimental site for the year 2015

Year	Months	Temperature (°C)	Relative humidity (%)	Rainfall (mm)
2015	January	21.32	61.03	0.59
	February	23.10	50.72	Nil
	March	25.34	58.70	2 mm (25.03.2015)
	April	25.87	66.55	Nil

Results and Discussions

Screening of germplasm accessions for drought tolerance

Analysis of variance

Analysis of variance revealed highly significant mean squares attributable to germplasm accessions for all traits. (Table 3). Mean squares attributable to 'Genotypes *vs* check entries' were significant for all traits except seeds per pod and relative water content. These results suggest significant differences among the germplasm accessions. The germplasm accessions as group differed significantly for all of the traits under investigation, similarly, check entries as group differed significantly for most the traits under study.

Correlation coefficients

Correlation coefficients are used to measure the strength of the relationship between two variables (dependent and independent). Pearson *correlation* is one of the most commonly used statistics hence, Pearson correlation was performed and is presented in table 4. The correlation coefficient analysis revealed that out of 17 independent variables studied, 15 variables showed positive correlation with dependent variable yield. Two variables which did not show positive correlation with yield are; days to 50% flowering, and days to maturity. Among the independent variables, pods per cluster had highest positive correlation with seed yield per plant (0.84) followed by pods per cluster (0.77), clusters per plant(0.71), plant height (0.68), proline content (0.63), spad chlorophyll meter reading (0.62), leaf water potential (0.61), harvest index and seeds per pod (0.60). Other independent variables showed lower positive magnitude of relation with dependent variable yield such as; pod length (0.56), primary branches per plant (0.52), relative water content (0.51), specific leaf area (0.41), test weight (0.40) and threshing percentage (0.17). Sandhiya and Saravanan (2018) [20] have also reported significant positive correlation with the traits; number of pods per plant, number of clusters per plant and number of pods per cluster.

Table 3: Summary of Augmented ANOVA for grain yield and component traits of germplasm accessions under drought condition

Sources of Variations	DF	DFF	DM	PH	CPP	PPC	PPP	PL	SPP	TW
Blocks (b)	4	14.74 **	8.18***	65.31**	2.23**	0.11*	25.23**	1.49**	5.05**	1.77 **
Entries (e) (Genotypes + Checks)	204	17.10 **	18.01**	84.47**	3.60**	0.51**	72.94**	0.75**	2.70**	0.35 **
Checks	4	34.57 **	37.01**	22.56**	1.40**	0.42**	12.50**	0.87**	3.98**	0.81 **
Genotypes	199	14.215 **	15.14**	85.71**	3.67**	0.51**	73.91**	0.73**	2.69**	0.31 **
Checks vs Genotypes	1	521.64 **	513.06**	85.01**	0.16**	1.45**	121.60**	4.52**	0.03	5.42 **
Error	16	1.32	0.74	0.98	0.04	0.02	0.98	0.009	0.05	0.05

Sources of Variations	DF	TP	HI	SCMR	LWP	PC	RWC	SLA	SYPP
Blocks (b)	4	37.12*	247.54 **	396.55 **	1.17 **	470.90 **	423.68 *	4067.34 *	2.11 **
Entries (e) (Genotypes + Checks)	204	37.20 **	54.41 *	98.71 **	2.45 **	1707.90 **	425.40 **	4283.10 **	7.01 **
Checks	4	17.09	64.39 *	24.49	0.82 **	942.07 **	63.06	1924.20	3.76 **
Genotypes	199	27.67 *	53.01 *	79.58 *	2.33 **	1712.67 **	433.68 **	4294.15**	7.10 **
Checks vs Genotypes	1	2014.79 **	293.20 **	4203.25 **	32.57 **	3822.09 **	227.32	11518.68**	0.42*
Error	16	9.83	19.57	31.14	0.03	1.48	130.64	1339.95	0.09

*Significant at P =0.05, ** Significant at P=0.01

DFF : Days to 50% flowering	PPP : Pods per plant	HI : Harvest index (%)	SLA : Specific leaf area
DM : Days to maturity	PL : Pod length (cm)	SCMR : SPAD Chlorophyll meter reading	SYPP : Seed yield per plant
PH : Plant height (cm)	SPP : Seeds per pod	LWP : Leaf water potential(Mpa)	
CPP : Cluster per plant	TW: Test weight	PC : Proline content (µg g^{-1})	
PPC : Pods per cluster	TP : Threshing %	RWC : Relative water content (%)	

Table 4: Correlation matrix (Pearson (n))

Variables	DFF	DM	PH	CPP	PPC	PPP	PL	SPP	TW	TP	HI	SCMR	LWP	PC	RWC	SLA	SYPP
DFF	1	0.97*	-0.20*	-0.28*	-0.10	-0.23*	-0.18*	-0.03	-0.23*	0.04	-0.13	-0.23*	-0.15*	-0.15*	-0.14*	-0.04	-0.22*
DM	0.97*	1	-0.23*	-0.27*	-0.12	-0.23*	-0.21*	-0.09	-0.21*	0.05	-0.16*	-0.28*	-0.21*	-0.20*	-0.22*	-0.10	-0.24*
PH	-0.20*	-0.23*	1	0.56*	0.59*	0.63*	0.41*	0.45*	0.29*	0.20*	0.39*	0.46*	0.49*	0.47*	0.39*	0.31*	0.68*
CPP	-0.28*	-0.27*	0.56*	1	0.53*	0.93*	0.12	0.09	0.10	0.13	0.32*	0.19*	0.24*	0.19*	0.06	0.01	0.71*
PPC	-0.10	-0.12	0.59*	0.53*	1	0.78*	0.38*	0.40*	0.21*	0.09	0.44*	0.50*	0.57*	0.52*	0.36*	0.32*	0.77*
PPP	-0.23*	-0.23*	0.63*	0.93*	0.78*	1	0.22*	0.20*	0.18*	0.13*	0.40*	0.32*	0.39*	0.32*	0.17*	0.12	0.84*
PL	-0.18*	-0.21*	0.41*	0.12	0.38*	0.22*	1	0.74*	0.26*	0.26*	0.53*	0.78*	0.64*	0.78*	0.74*	0.65*	0.56*
SPP	-0.03	-0.09	0.45*	0.09	0.40*	0.20*	0.74*	1	0.09	0.15*	0.55*	0.78*	0.72*	0.82*	0.76*	0.65*	0.60*

TW	-0.23*	-0.21*	0.29*	0.10	0.21*	0.18*	0.26*	0.09	1	-0.03	0.20*	0.19*	0.11	0.15*	0.15*	0.06	0.40*
TP	0.04	0.05	0.20*	0.13	0.09	0.13*	0.26*	0.15*	-0.03	1	0.10	0.16*	-0.02	0.09	0.02	0.13*	0.17*
HI	-0.13	-0.16*	0.39*	0.32*	0.44*	0.40*	0.53*	0.55*	0.20*	0.10	1	0.70*	0.70*	0.74*	0.61*	0.34*	0.60*
SCMR	-0.23*	-0.28*	0.46*	0.19*	0.50*	0.32*	0.78*	0.78*	0.19*	0.16*	0.70*	1	0.80*	0.91*	0.79*	0.60*	0.62*
LWP	-0.15*	-0.21*	0.49*	0.24*	0.57*	0.39*	0.64*	0.72*	0.11	-0.02	0.70*	0.80*	1	0.93*	0.77*	0.60*	0.61*
PC	-0.15*	-0.20*	0.47*	0.19*	0.52*	0.32*	0.78*	0.82*	0.15*	0.09	0.74*	0.91*	0.93*	1	0.86*	0.67*	0.63*
RWC	-0.14*	-0.22*	0.39*	0.06	0.36*	0.17*	0.74*	0.76*	0.15*	0.02	0.61*	0.79*	0.77*	0.86*	1	0.66*	0.51*
SLA	-0.04	-0.10	0.31*	0.01	0.32*	0.12	0.65*	0.65*	0.06	0.13*	0.34*	0.60*	0.60*	0.67*	0.66*	1	0.41*
SYPP	-0.22*	-0.24*	0.68*	0.71*	0.77*	0.84*	0.56*	0.60*	0.40*	0.17*	0.60*	0.62*	0.61*	0.63*	0.51*	0.41*	1

Values in bold* are significantly different at alpha=0.05

DFF : Days to 50% flowering	PPP : Pods per plant	HI : Harvest index (%)	SLA : Specific leaf area
DM : Days to maturity	PL : Pod length (cm)	SCMR : SPAD Chlorophyll meter reading	SYPP : Seed yield plant^{-1}
PH : Plant height (cm)	SPP : Seeds per pod	LWP : Leaf water potential(Mpa)	
CPP : Cluster per plant	TW: Test weight(g)	PC : Proline content(µg g^{-1})	
PPC : Pods per cluster	TP : Threshing %	RWC : Relative water content (%)	

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