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Response of Water Stress on Morphological Characteristics of *Vigna radiata* L. Genotypes

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ABSTRACT

Considering water scarcity, the current study was carried out to evaluate mung bean genotypes for morphological properties in a dehydration situation. The current experiment was carried out at the pot house of Baba Mastnath University, Asthal Bohar, Rohtak, during two *kharif* seasons of 2019-20 and 2021-22. The experiment was set up in a completely randomized design, with two environments and eight genotypes in three replications for root and shoot length, number of leaves/plant, number of flowers/plant, nodules/plant, number of secondary branches/plant, root, leaf and nodule fresh and dry weight. Drought condition was maintained by the withholding of adequate water supply, whereas in the control pots, water was applied up to field capacity. Drought application showed a reduction in mean root length (12.1 to 10.7 cm) and shoot length (24.5-18.0 cm), number of leaves/plant (8.8-6.7), number of flowers/plant (27.4-23.8), nodules/plant (8.8-6.9), number of secondary branches/plant (6.4-4.3), root (11.5-6.3 g; 5.07-2.82 g), leaf (7.35-5.33 g; 3.94-1.87 g) and nodule (5.17-3.04 g; 2.76-1.19 g) weight, respectively. In all tested genotypes PAU-911 and MH-318 genotypes were found to have tremendous potential under drought conditions.

Key words: Drought, irrigated, morphological characteristics, mung bean

INTRODUCTION

India is the main producer, consumer and exporter of mungbean (Singh *et al.,* 2016). Despite being an economically essential crop, overall production of mungbean is low due to abiotic and biotic stresses (Bangar *et al.,* 2018). Grain legumes, including pigeonpea, chickpea, cowpea, lentil, dry pea and mungbean are the major dietary sources of protein for vegetarians, and constitute an essential part of the daily food in various forms worldwide. The mungbean [*Vigna radiata* (L.) Wilczek] is self-pollinating, diploid (2n=22) growing quickly (around 60 days) sometimes also referred as the moong bean, green gramme, or mugda. It is the third most significant pulse crop after chickpea and pigeonpea. It is the perfect bean for mixed cropping, short duration nitrogen-fixing symbiont (Allito *et al.,* 2015).

Drought stress leads to imbalanced assimilates and decreases sucrose content, ultimately reducing the export rate from source to sink and dry matter partitioning by stress (Zhou *et al.,* 2019). At the initial stage, drought stress affects seed germination and decreases seedling formation due to affected cell division and cell elongation, leading to poor crop growth (Hussain *et al.,* 2018). Mungbean has the capacity to fix nitrogen by symbiosis with nitrogen-fixing *Rhizobium* bacterium (Allito *et al.,* 2015). Roots play a vital role in drought stress tolerance by reduction in leaf expansion and promotion of root growth (Kumar *et al.,* 2015). Plant growth is primarily accomplished by cell division, enlargement and differentiation. Drought impairs mitosis and cell elongation which results in weak growth and shoot length and are also decreased under the drought stress conditions (Faucon *et al.,* 2017). The root system is an essential organ for water acquisition and nutrient absorption throughout a plant's life (Zhao *et al.,* 2017). A common contrary effect of water stress on crop plants is the reduction in fresh and dry biomass production (Durigon *et al.,* 2019). It has been found that water stress reduced the dry mass of both shoot and root as well as the total plant dry weight in soybean (Mangena, 2018). The crop suffering water stress resulted in decreased seed yield, pod number, number of seeds/pod and 1000-seed weight (Swathi *et al.,* 2017). Associations between yield and morpho-physiological characteristics have been reported in many plant species including mungbean (Sharafi *et al.,* 2014). Keeping in view the above facts, this research was conducted to find out the effect of drought on the morphological characteristics in mungbean genotypes.

MATERIALS AND METHODS

Seeds of selected mungbean genotypes, namely, ASHA, MH-318, MUSKAN, PAU-911, PUSA, SAMRAT and Satya were obtained from CCS Haryana Agricultural University, Hisar. These eight genotypes were cultivated in irrigated as well as drought conditions under two environments (irrigated and non-irrigated), in three replications (completely randomized design) in the pot house in the laboratory of Department of Botany, Baba Mastnath University, Asthal Bohar, Rohtak during two *kharif* seasons of 2019-20 and 2021-22.

The root and shoot lengths were measured in cm. The number of nodules on the primary and secondary root systems of plants was determined by counting the nodules. At the time of harvest, the average number of secondary branches per completely grown plant was manually determined. Before and after stress, the total number of leaves was manually determined using three fully formed leaflets (Ram et al., 2018). Using an electric balance, the weight of fresh and dried leaves, roots and nodules was determined. The fresh weight was collected immediately upon sampling, whereas the dry weight was measured three days after drying in an 80°C hot air oven. Triplicate data were analyzed using op-stat (online statistical tool by CCS Haryana Agricultural University, Hisar; http://14.139.232.166/opstat/). Significance was tested at 0.05.

RESULTS AND DISCUSSION

A signification reduction in root length was observed in all genotypes under control and drought stress condition (Table 1). Root length varied between 9.9±0.030 to 14.4±0.035 cm under control, whereas 8.9±0.104 to 12.3±0.238 cm under water restricted environment. Maximum root length (14.4 cm) was observed in mungbean genotype PAU-911 followed by MH-318 (13.4 cm), whereas minimum root length (9.9 cm) was observed in MUSKAN under both tested environments. On set of drought reduced mean root length from 12.1 to 10.7 cm and drought stress resulted in a reduction of mean number of root length in all genotypes ranging from 13.39 to 9.45 under stress. All tested genotypes had significant interaction effect with each other as well as both tested environments. Root length at seedling stage provided a fair estimate about the root growth in field (Kumar *et al.,* 2015). The root length and distribution of root conductivity-regulating metaxyl vessels were also documented to provide drought tolerance in food grain legumes (Purushothaman *et al.,* 2017). Drought stress also greatly impacted the nutrients uptake by plant roots system along with water (Bista *et al.,* 2018) due to reduced root growth in drought conditions.

All genotypes exhibited a significant reduction in shoot length between control and drought

Table 1. Effect of drought condition on root length and shoot length (cm) in mungbean genotypes

Genotypes	Root length (cm)			Shoot length (cm)		
	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)
ASHA	10.6±0.149	9.1±0.092	9.91	24.5±0.361	16.6±0.120	20.6
MH-318	13.4±0.071	12.5±0.016	13.02	26.8±0.624	21.9±0.208	24.4
MUSKAN	9.9±0.030	8.9±0.104	9.45	22.8±0.473	14.4±0.208	18.6
PAU-911	14.4±0.035	12.3±0.238	13.39	26.1±0.624	23.6±0.153	24.9
PM-5	12.1±0.000	11.1±0.047	11.65	21.7±0.153	19.3±0.384	20.5
PUSA	12.0±0.122	10.4±0.000	11.26	20.0±0.208	13.7±0.088	16.9
SAMRAT	12.9±0.211	11.7±0.092	12.34	28.4±0.536	18.4±0.296	23.5
Satya	10.9±0.191	9.5±0.092	10.27	25.4±0.536	15.9±0.176	20.7
Mean (T)	12.1	10.7		24.5	18.0	
Factors	C. D.	SE(d)	SE(m)	C. D.	SE(d)	SE(m)
Treatment (T)	0.12	0.059	0.042	0.377	0.184	0.13
Genotypes (G)	0.24	0.117	0.083	0.754	0.369	0.261
Interaction (T x G)	0.34	0.166	0.117	1.067	0.521	0.369

stress conditions (Table 1). The shoot length ranged from 20.0±0.208 to 26.8±0.624 cm in a controlled environment and from 13.7±0.088 to 23.6±0.153 cm in a water-restricted environment. Under both studied situations, the mungbean genotype having the maximum shoot length was PAU-911 (24.9 cm), followed by MH-318 (24.4 cm). The onset of drought decreased the average root length from 24.5 to 18.0 cm, while drought stress reduced the average root length of all genotypes from 24.9 to 16.9 cm. Each examined genotype had a strong interaction impact with the other genotypes, and both settings exhibited a significant interaction effect with each other. Water shortage disturbed normal turgor pressure, and the loss of cell turgidity which may stop cell enlargement that causes reduced plant growth (Bangar *et al.,* 2018). Some studies established that as water stress increased, the shoot dry matter was progressively reduced in mungbean (Kumari and Chakraborty, 2019).

The investigated mungbean genotypes for number of leaves per plant in all genotypes under control and under drought stress saw a significant reduction (Table 2). The range of number of leaves per plant in the control and water-restricted environments was 6.0±0.078 to 10.1±0.131 and 4.7±0.024 to 8.3±0.184, respectively. Mungbean genotype PAU-911 had the maximum leaf (9.26), followed by MH-318 (9.03), whereas genotype PUSA had the minimum leaf number (5.39) in each of the test conditions. After drought stress, the mean number of leaves per plant in all genotypes decreased from 10.1 to 8.3, whereas before the start of the drought it was 6.0 to 4.7. Interaction effect between genotype, treatment and stress level was statistically significant. Under drought stress, leaf area reductions were observed in many plant species (Larkunthod *et al.,* 2018).

The investigated mungbean genotypes for number of flowers per plant in all genotypes under control and under drought stress saw a significant reduction. The range of number of flowers per plant in the control and water-restricted environments was 24.5±0.153 to 30.0±0.153 and 21.1±0.448 to 25.7±0.48, respectively (Table 2). Mungbean genotype MH-318 had the maximum flower (28.12), followed by PAU-911(27.87), whereas genotype PUSA had the minimum flower number (22.83) in each of the test conditions. After drought stress, the mean number of flowers per plant in all genotypes decreased from 30.0 to 25.7 on an average, from 24.5 to 21.1 before the start of the drought. Interaction effect between genotype, treatment and stress level was statistically significant. Drought existence at flower formation controlled to a shorter flowering period and produced fewer flowers, fewer pods and thus, a smaller number of seeds per plant. Drought induced early flowering though it was not economical due to poor pod setting under drought stress. Water deficiency at the flowering stage caused flower and pod abortion resulting in small-sized seeds (Nair *et al.,* 2019). Nadeem *et al.* (2019) reported yield loss in the range of 31-60% at flowering and 26% at post-flowering/podding stages in mungbean due to drought stress.

Table 2. Effect of drought condition on number of leaves/plant and number of flowers/plant in mungbean genotypes

Genotypes	Number of leaves/plant			Number of flower/plant		
	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)
ASHA	8.4±0.045	7.1±0.161	7.82	27.2±0.384	24.7±0.120	26.02
MH-318	9.9±0.098	8.1±0.004	9.03	29.7±0.240	26.5±0.208	28.12
MUSKAN	6.5±0.000	5.6±0.137	6.13	26.4±0.328	22.7±0.176	24.60
PAU-911	10.1±0.131	8.3±0.184	9.26	30.0±0.153	25.7±0.481	27.87
PM-5	6.3±0.107	5.0±0.107	5.68	25.7±0.504	21.8±0.322	23.77
PUSA	6.0±0.078	4.7±0.024	5.39	24.5±0.153	21.1±0.448	22.83
SAMRAT	8.0±0.170	6.5±0.139	7.28	27.1±0.681	23.3±0.504	25.23
Satya	9.9±0.203	7.8±0.045	8.90	28.9±0.088	24.6±0.536	26.80
Mean (T)	8.8	6.7		27.47	23.84	
Factors	C. D.	SE(d)	SE(m)	C. D.	SE(d)	SE(m)
Treatment (T)	0.122	0.06	0.042	0.384	0.188	0.133
Genotypes (G)	0.244	0.119	0.084	0.768	0.375	0.265
Interaction (T x G)	0.346	0.169	0.119	N/A	0.531	0.375

The number of nodules per plant had significant reduction in number of nodules per plant in all mungbean genotypes along control and drought stress condition (Table 3). Number of nodules per plant varied between 10.8±0.001 to 9.9±0.074 under control, whereas 9.0±0.118 to 8.0±0.17 under water-restricted environment. Maximum nodules per plant (14.4) were observed in mungbean genotype PAU-911 followed by MH-318 (13.4), whereas minimum nodules (9.9) were observed in mungbean genotype MUSKAN under both tested environments. Onset of drought reduced mean nodules per plant from 8.8 to 6.9 and drought stress resulted in a reduction of mean number of nodules in all genotypes ranging from 9.82 to 6.60 after stress. All tested genotypes had significant interaction effect with each other as well as both tested environments and between each other. Many non-rhizobial bacteria (NRB) genera have been identified in studies in the microbial community of legume root nodules (Hakim *et al.,* 2018). It was typical to find a rhizobial genus predominating in legume nodules (Zheng *et al.,* 2020).

The number of secondary branches per plant had significant variation among the tested mungbean genotypes. Data showed a signification reduction in number of secondary branches per plant in all genotypes along control and drought stress condition (Table 3). Number of secondary branches per plant varied between 7.4±0.074 to 7.2±0.131 under control, whereas 5.5±0.123 to 5.1±0.089 under water-restricted environment. Maximum number of secondary branches per plant (7.4) was observed in mungbean genotype PAU-911 followed by MH-318 (7.2), whereas minimum secondary branches (4.8) was observed in mungbean genotype PM-5 under both tested environments. Onset of drought reduced mean number of secondary branches per plant from 6.4 to 4.3 and drought stress resulted in a reduction of mean number of nodules in all genotypes ranged from 6.52 to 3.82 after stress. All tested genotypes had significant interaction effect with each other as well as both tested environments also showed significant interaction between each other. Sarkar and Kundagrami (2016) analyzed agro-morphological traits including days to number of branches and number of secondary branches in mungbean genotype reduction with restriction of water supply. High yielding varieties of mungbean significantly set greater secondary branches numbers with yield (Singh and Kumar, 2014).

The root fresh weight had significant variation among the tested mungbean genotypes. Data showed a signification reduction in root fresh weight in all genotypes along control and drought stress condition (Table 4). Root fresh weight varied between 10.5±0.259 to 9.4±0.137 under control, whereas 7.9±0.074 to 7.6±0.083 under water restricted environment. Maximum root fresh weight (10.5) was observed in mungbean genotype PAU-911 followed by MH-318 (9.4), whereas minimum root fresh weight (5.2) was observed in mungbean genotype PUSA under both tested environments. Onset of drought reduced mean

Table 3. Effect of drought condition on number of nodules/plant and secondary branches/plant in mungbean genotypes

Genotypes	Number of nodules/plant			No. of secondary branches/plant		
	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)
ASHA	7.7±0.095	6.0±0.09	7.00	6.8±0.354	4.7±0.042	5.80
MH-318	9.9±0.074	8.0±0.17	8.95	7.2±0.131	5.1±0.089	6.20
MUSKAN	7.0±0.068	5.9±0.08	6.60	6.1±0.083	3.9±0.068	5.00
PAU-911	10.8±0.001	9.0±0.118	9.82	7.4±0.074	5.5±0.123	6.52
PM-5	8.9±0.196	7.1±0.089	7.94	4.8±0.050	2.7±0.018	3.82
PUSA	7.8±0.018	5.8±0.083	7.05	5.5±0.113	3.3±0.018	4.45
SAMRAT	9.5±0.089	7.7±0.024	9.06	6.2±0.003	4.2±0.090	5.28
Satya	7.1±0.146	4.9±0.018	6.02	6.8±0.146	4.5±0.056	5.71
Mean (T)	8.8	6.9		6.4	4.3	
Factors	C. D.	SE(d)	SE(m)	C. D.	SE(d)	SE(m)
Treatment (T)	0.102	0.05	0.35	0.123	0.06	0.043
Genotypes (G)	0.205	0.10	0.07	0.247	0.12	0.085
Interaction (T x G)	0.29	0.142	0.1	N/A	0.17	0.12

root fresh weight from 11.5 to 6.3. Drought stress resulted in a reduction of mean root fresh weight in all genotypes ranging from 12.29 to 6.78 after stress. All tested genotypes had significant interaction effect with each other as well as both tested environments also showed significant interaction between each other. Fresh and dry root weight was also decreased due to water stress in mungbean. Under 20% (w/v) drought condition, genotypes PEG and K-851 had higher root fresh weight and dry weight than PDM-139 (Kumar *et al.,* 2020).

The root dry weight had significant variation among the tested mungbean genotypes. Data showed a signification reduction in root dry weight in all genotypes along control and drought stress condition (Table 4). Root dry weight varied between 6.0±0.045 to 5.0±0.066 under control, whereas 3.1±0.074 to 2.8±0.006 under water-restricted environment. Maximum root dry weight (6.0) was observed in mungbean genotype PAU-911 followed by MH-318 (5.0), whereas minimum root dry weight (2.1) was observed in mungbean genotype PUSA under both tested environments. Onset of drought reduced mean root dry weight from 5.07 to 2.82 and drought stress resulted in a reduction of mean root dry weight in all genotypes ranging from 6.26 to 2.26 after stress. All tested genotypes had significant interaction effect with each other as well as both tested environments also showed significant interaction between each other. It was found that water stress reduced the dry weight of both shoot and root as well as the total plant dry weight in soybean (Abdelhamid *et al.,* 2014). Dry and fresh weights of roots decreased during the drought period as their leaf size remained small to minimize transpiration, thus reducing plant dry weight (Bangar *et al.,* 2018).

The investigated mungbean genotypes for leaf fresh weight in all genotypes under control and under drought stress saw a significant reduction. The range of fresh weight of leaves in the control and water-restricted environments was 9.2±0.146 to 15.0±0.125 and 4.3±0.015 to 9.5±0.039, respectively (Table 5). Mungbean genotype PAU-911 had the maximum leaf weight (9.27), followed by MH-318 (8.59), whereas genotype PUSA had the minimum leaf fresh weight (4.29) in each of the test conditions. After drought stress, the mean number of leaf fresh weight in all genotypes decreased from 15.0 to 9.5 and from 9.6 to 4.5 before the start of the drought. Interaction effect between genotype, treatment and stress level was statistically significant. The enhancement of leaf area as well as leaf fresh weight was demonstrated by Rahman *et al.* (2018) in *V. radiata.*

The investigated mungbean genotypes for leaf dry weight in all genotypes under control and under drought stress saw a significant reduction. The range of number of leaf dry weight in the control and water-restricted environments was 3.4±0.026 to 7.7±0.086 and 1.0±0.009 to 4.7±0.018, respectively (Table 5). Mungbean genotype PAU-911 had the maximum leaf dry weight (4.59), followed by MH-318 (3.95), whereas genotype PUSA had the minimum leaf number (1.39) in each of the test conditions. After drought stress, the mean

Table 4. Effect of drought condition on fresh and dry weight of root in mungbean genotypes

Genotypes	Root fresh weight (g)			Root dry weight (g)		
	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)
ASHA	7.1±0.119	5.3±0.113	8.81	4.3±0.042	2.1±0.030	4.12
MH-318	9.4±0.137	7.6±0.083	10.70	5.0±0.066	2.8±0.006	5.25
MUSKAN	6.1±0.155	4.2±0.083	7.81	3.0±0.045	1.3±0.003	3.24
PAU-911	10.5±0.259	7.9±0.074	12.29	6.0±0.045	3.1±0.074	6.26
PM-5	6.0±0.104	3.6±0.057	7.12	2.4±0.030	0.8±0.019	2.65
PUSA	5.2±0.059	3.3±0.026	6.78	2.1±0.033	0.6±0.000	2.26
SAMRAT	6.4±0.044	4.6±0.038	8.13	3.7±.006	1.6±0.033	3.55
Satya	7.6±0.033	5.8±0.038	9.42	4.6±0.077	2.4±0.026	4.25
Mean (T)	11.5	6.3		5.07	2.82	
Factors	C. D.	SE(d)	SE(m)	C. D.	SE(d)	SE(m)
Treatment (T)	0.109	0.053	0.038	0.042	0.02	0.014
Genotypes (G)	0.217	0.106	0.075	0.083	0.041	0.029
Interaction (T x G)	0.307	0.15	0.106	0.118	0.058	0.041

Table 5. Effect of drought condition on fresh and dry weight of leaf in mungbean genotypes

Genotypes	Leaf fresh weight (g)			Leaf dry weight (g)		
	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)
ASHA	10.7±0.169	6.5±0.015	6.28	5.0±0.054	3.1±0.065	3.22
MH-318	13.6±0.036	7.7±0.184	8.59	6.3±0.113	4.1±0.054	3.95
MUSKAN	10.3±0.074	5.2±0.116	5.17	4.2±0.059	2.1±0.021	2.21
PAU-911	15.0±0.125	9.5±0.039	9.27	7.7±0.086	4.7±0.018	4.59
PM-5	9.6±0.019	4.5±0.026	4.83	3.7±0.095	1.5±0.033	1.65
PUSA	9.2±0.146	4.3±0.015	4.29	3.4±0.026	1.0±0.009	1.39
SAMRAT	10.7±0.184	5.4±0.015	5.55	4.6±0.033	2.4±0.057	2.72
Satya	12.1±0.092	6.7±0.057	6.73	5.1±0.066	3.3±0.078	3.51
Mean (T)	7.35	5.33		3.94	1.87	
Factors	C. D.	SE(d)	SE(m)	C. D.	SE(d)	SE(m)
Treatment (T)	0.105	0.051	0.036	0.063	0.031	0.022
Genotypes (G)	0.21	0.103	0.073	0.125	0.061	0.043
Interaction (T x G)	0.297	0.145	0.103	0.177	0.087	0.061

number of leaf dry weight in all genotypes decreased from 7.7 to 4.7 on average, and from 3.7 to 1.5 before the start of the drought. Interaction effect between genotype, treatment and stress level was statistically significant. Jothimani and Rajendran (2022) found that dry weight of leaves per plant decreased with the increase of drought intensity. Hossain *et al.* (2018) also reported reduction in leaf dry weight of mungbean in plots intercropping with maize compared to sole mungbean under dry condition.

The fresh weight of nodules had significant variation among the tested mungbean genotypes. A signification reduction was found in fresh weight of nodules in all genotypes along control and drought stress condition (Table 6). Fresh weight of nodules varied between 3.5±0.058 to 7.7±0.009 under control, whereas 2.9±0.434 to 5.5±0.563 under water restricted environment. Maximum fresh weight of nodules (7.7) was observed in mungbean genotype PAU-911 followed by MH-318 (6.1), whereas minimum fresh weight of nodules (3.5) was observed in mungbean genotype Satya under both the tested environments. Onset of drought reduced mean fresh weight of nodules from 5.17 to 3.04 and drought stress resulted in a reduction of mean fresh weight of nodules in all genotypes ranging from 6.21 to 2.68 after stress. All tested genotypes had significant interaction effect with each other as well as both the tested environments also showed significant interaction between each other. Mungbean genotype subjected to low water environment showed reduction in fresh/dry weight (Fenta *et al.,* 2014).

The dry weight of nodules had significant variation among the tested mungbean genotypes. Fresh weight of nodules varied between 1.4±0.024 to 4.6±0.026 under control, whereas 1.0±0.334 to 3.0±0.403 under water

Table 6. Effect of drought condition on fresh and dry weight of nodules in mungbean genotypes

Genotypes	Nodules fresh weight (g)			Nodules dry weight (g)		
	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)	Control (Mean±SE)	Drought (Mean±SE)	Mean (G)
ASHA	5.2±0.131	4.4±0.054	4.43	2.6±0.007	2.2±0.015	1.95
MH-318	6.1±0.445	5.5±0.563	5.13	3.4±0.376	3.0±0.403	2.76
MUSKAN	5.6±0.734	5.2±0.865	3.28	3.1±0.575	2.6±0.735	1.44
PAU-911	7.7±0.009	3.6±0.049	6.21	2.1±0.024	1.2±0.015	3.68
PM-5	3.9±0.026	3.7±0.054	3.06	4.6±0.026	1.7±0.045	1.09
PUSA	5.0±1.314	2.9±0.434	2.68	2.6±0.970	1.0±0.334	0.81
SAMRAT	3.7±0.044	3.2±0.678	3.31	1.6±0.095	1.4±0.688	1.63
Satya	3.5±0.058	4.7±0.116	4.73	1.4±0.024	2.6±0.018	2.45
Mean (T)	5.17	3.04		2.76	1.19	
Factors	C.D.	SE(d)	SE(m)	C.D.	SE(d)	SE(m)
Treatment (T)	0.08	0.039	0.028	0.036	0.018	0.012
Genotypes (G)	0.159	0.078	0.055	0.072	0.035	0.025
Interaction (T x G)	0.225	0.11	0.078	0.102	0.05	0.035

restricted environment (Table 6). Maximum dry weight of nodules (4.6) was observed in mungbean genotype PM-5 followed by MH-318 (3.4), whereas minimum dry weight of nodules (1.4) was observed in mungbean genotype Satya under both the tested environments. Onset of drought reduced mean dry weight of nodules from 2.76 to 1.19 and drought stress resulted in a reduction of mean dry weight of nodules in all genotypes ranging from 3.68 to 0.81 after stress. All tested genotypes had significant interaction effect with each other as well as both tested environments also showed significant interaction between each other. Alderfasi *et al.* (2017) reported similar morpho-physiological variations under variable environmental stress conditions.

CONCLUSION

Mungbean is sensitive to water stress and water stress significantly affects on root system, shoot bio mass production and final yield. Effects of drought reduced morphological parameters (root length and shoot length (cm), number of leaves/plant and number of flowers/ plant, number of nodules/plant and number of secondary branches/plant, and fresh and dry weight of root, leaf, nodules) and ultimately yield. Genotypes PAU-911 and MH-318 were found best and promising in overall performance for use in order to improve yield for future breeding program.

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