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Performance of blackgram genotypes under moisture deficit stress - Variability in physiological and yield contributing attributes

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Abstract

Water deficit stress is the most important abiotic stresses which affects the physiological parameters and crop yield. Blackgram (*Vigna mungo* L. Hepper) is one of the highly prized pluses in India and second most important pulse crop. A field experiment was conducted with seventeen blackgram genotypes during 2014 to assess the impact of water deficit stress on physiological parameters such as Anet, gs, Tr, WUE, SPAD chlorophyll meter reading (SCMR) and yield parameters (i.e.) pod number, seed number, pod weight and seed yield. Imposing water deficit stress at flowering stage, the reduction of physiological and yield parameters were observed. The results indicated that a wide diversity among the genotypes in their physiological and yield related parameters under both moisture levels. The genotype IC398971 was found to be physiologically efficient even with water deficit stress and also recorded moderate seed yield. While the genotype PU-19 with moderate physiological values registered highest seed yield under both well watered and water deficit stress conditions. Among the selected germplasm these two genotypes are having tolerant to water deficit stress with better stability of physiological and yield parameters.

Keywords: blackgram genotypes, water deficit stress, Anet, WUE, yield

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Introduction

Environmental changes can influence crop growth and there by yield in nature due to abiotic and biotic stresses. These abiotic and biotic stresses brings changes in yield due to physiological, biochemical parameters from a mild to the larger extent (Baroowa and Gogoi, 2012, 2013). Among different stresses, water deficit stress occurs over 1.2 billion hectares of rainfed agricultural land, reducing crop yield worldwide (Boyer, 1982; Kijne, 2006). The predicted global climatic changes such as increased temperatures, changes in rainfall pattern and consequent availability of water to crops at critical growth stages are likely to affect the crop productivity in general and pulse crops in particular (Ali and Gupta, 2012). Increased temperatures further reduce the crop duration of the short-duration pulses like mungbean and urdbean and this will lower the yield.

Black gram (*Vigna mungo* L. Hepper) is an important food legume and it has high nutritive value with 24-26% protein. Lack of suitable genotypes with adaptation to environmental conditions like water deficit conditions are the factors affecting blackgram production. 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, at flowering and the post-flowering stages of pulse crops has been found to have a greater adverse impact than at the vegetative stage (Cortes and Suidaria, 1986; Uprety and Bhatia, 1989). 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 cultivars that can tolerate drought with reasonable grain yield. The present experiment was conducted to assess the physiological and yield related parameters of seventeen blackgram genotypes under water deficit stress condition.

Materials and Methods

A field experiment was laid out with seventeen blackgram genotypes during summer 2014 at Research farm of Central Research Institute for Dryland Agriculture, Hyderabad, situated at 17°18-N latitude, 78°36-E longitude and 515 m above msl. The selected seventeen blackgram genotypes are IC281987, IC282009, IC343947, IC343952, IC398971, IC436519, IC436610, IC436652, IC436720, IC436753, IC519805, IC587751, IC587752, IC587753, PU-19, LBG-20 and T-9 and their performance was evaluated to water deficit stress at flowering stage. The experiment was sown on 5-2-2014 in RBD in three replications with a plot of size of 6 x 6 m and spacing of 30 cm for row to row and 10 cm for plant to plant. Two moisture levels were well watered controls and water deficit stress. The well watered controls were maintained by providing irrigation at regular intervals while water deficit stress was imposed at flowering stage by withholding irrigation till wilting symptoms were observed there after stress was released by irrigating the plots. All the recommended cultural practices were followed for raising a good field crop. Physiological observations were recorded during water deficit stress period and yield contributing parameters were recorded at harvest. Net photosynthetic rate (Anet) was measured on fully expanded young leaves of control and water deficit (WD) treatment with a portable photosynthesis system LI-6400 (LI-COR, Lincoln, USA). Measurement of photosynthetic rate (Anet) along with stomatal conductance (gs), transpiration rate (Tr) were recorded between 10:00 and 12:00 hrs, with irradiance set at 1200 µmol m^{-2} s^{-1} and a constant 390 ppm of CO_2 in the sample chamber. Water use efficiency (WUE) was calculated as the ratio of Anet and Tr. SPAD (Soil Plant Analytical Development) chlorophyll meter Model SPAD 502 plus (Konica Minolta Inc.) was used for measuring the relative chlorophyll content (SCMR) of leaves.

Table 1. Analysis of variance for Physiological and yield parameters

	Genotypes	Moisture levels	Genotypes x moisture levels
Physiological parameters			
Anet	**	**	**
Gs	**	**	**
Tr	**	**	**
WUE	**	**	**
SPAD reading	**	**	**
Yield parameters			
Pod number	**	**	**
Seed number	**	**	**
Pod weight	**	**	**
Seed yield	**	**	**

** Significant at (p<0.01) level

The observations were recorded on three different areas of fully expanded young leaf of each genotype and averaged. Data was retrieved in triplicates for individual genotypes. Meteorological data during crop season was obtained from weather station set near the experimental plots. The average temperature was 33.6°C with a minimum of 13.9°C and maximum of 39.5°C and the average RH was 39.7% with a minimum of 16 and maximum of 75%. During crop growth period the total rainfall received was 60.8 mm in 6 rainy days. The twofactor analysis of variance (ANOVA) was carried out for genotypes, moisture levels and their interaction at $p<0.05$ and $p<0.01$ significance level.

Results and Discussion

The ANOVA results of all physiological parameters- Anet, gs, Tr, SCMR and WUE as well as yield parameters- pod number, pod weight, seed number and seed yield were highly significant ($p<0.01$) for genotypes, moisture levels and their interaction (Table 1). Water deficit stress reduced the physiological and yield parameters and there was significant genotypic variability among seventeen blackgram genotypes that were selected.

Physiological parameters

The water deficit stress significantly reduced all the physiological parameters- Anet (38%), gs (56%), Tr (32%), WUE (7%) and SCMR (17%) of selected blackgram genotypes. Photosynthesis is an important physiological parameter, main source of energy of the plant system and can negatively affect by water deficit stress. Photosynthetic rate of all the selected genotypes reduced significantly under water deficit stress as compared to their respective controls. The mean performance of Anet under well watered and water deficit stress conditions were 32.37 µmol CO_2 $m^{-2}s^{-1}$ and 20.31 µmol CO_2 $m^{-2}s^{-1}$ respectively. Under well watered treatment the Anet of the genotypes ranged from 24.70 µmol CO_2 $m^{-2}s^{-1}$ (IC 436753) to 37.60 µmol CO_2 $m^{-2}s^{-1}$ (IC 587752) while with water deficit stress it was from 8.99 µmol CO_2 $m^{-2}s^{-1}$ (IC 343947) to 30.37 µmol CO_2 $m^{-2}s^{-1}$ (IC 398971). The percent of reduction of Anet ranged from 0.65% (IC 398971) to 74.37% (IC 343947). The genotype IC 398971 recorded highest Anet (30.37 µmol CO_2 $m^{-2}s^{-1}$) under water deficit stress though recorded moderate Anet (30.57 µmol CO_2 $m^{-2}s^{-1}$) at well watered conditions. Similar trend was observed with genotypes IC436720, IC587753, PU-19, LBG 20, T-9 with less impact of water deficit stress on Anet. Decrease in Anet due to moisture deficit stress was also recorded in blackgram (Siva Nageshwara Rao et al., 2015), sorghum (Vijayalakshmi et al., 2012) and groundnut (Vaidya et al., 2015). Many regulatory mechanisms will take place in plant system in order to protect them from ill effects of drought stress. Among these, stomatal closure is the immediate response to avoid excessive water loss through transpiration. Stomatal conductance decreased under water deficit stress conditions from 23.21% (LBG-20) to 75.6% (IC436610). There was a significant genotypic variability for gs response to water deficit stress and the genotypes IC587753 and IC436610 though recorded similar gs under well watered control conditions (0.65 cms^{-1} and 0.67 cms^{-1}), it is interesting to mention that a drastic reduction in gs under water deficit stress conditions was observed with IC436610 (0.16 cms^{-1}) while the response of IC587753 (0.40 cms^{-1}) was moderate.

Previous report by Gupta et al. (2009) revealed that there was variability in gs response of blackgram genotypes to sever water stress. Under water deficit stress, Tr decreased significantly from 6.76 mmol $m^{-2}s^{-1}$ (IC436610) to 12.33 mmol $m^{-2}s^{-1}$ (T-9) compared to well water conditions where it ranged from 12.47 mmol $m^{-2}s^{-1}$ (IC436753) to 15.67 mmol $m^{-2}s^{-1}$ (T-9). The lowest Tr under both moisture conditions was recorded by genotype IC436753 while highest by T-9. Morardi et al. (2008) reported reduction in Tr of mungbean under water deficit stress condition. The average intrinsic WUE decreased with water deficit stress (2.11 µmol CO_2/mmol H_2O) compared to irrigated conditions (2.34 µmol CO_2/mmol H_2O). However in most of the selected genotypes the *per se* values of WUE decreased under water deficit stress as compared with well watered condition, except in genotypes IC 282009, IC 436610, IC 436720, IC 436753, and T-9. Due to water deficit stress conditions the genotype IC 436610 recorded higher intrinsic WUE as it could maintain Anet and lowered its Tr. According to Rahbarian et al. (2011) in chickpea the WUE decreased due to water deficit stress whereas Ludlow and Muchow (1990) reported improved water use efficiency under drought condition and this increase may be due to the mechanism of leaf movement, increased leaf reflectance and temporary stomatal closure during periods of peak evaporative demand.

Higher SCMR means greater nitrogen and chlorophyll and thus these values can considered as an index for evaluation of genotypes for drought tolerance. The chlorophyll content reduces with abiotic stresses and more with drought stress. In the present investigation, the blackgram genotypes SPAD values ranged from 39.77 (IC398971) to 53.90 (PU-19) with an average of 46.01 under well watered treatment where as with water deficit stress it ranged from 34.07 (IC 398971) to 44.20 (IC343947) with an average of 38.08. Similar observations were recorded in sorghum (Devkumar et al., 2014) and in cowpea genotypes (Hayatu et al., 2010) the percentage of reduction in chlorophyll content in moderate stress ranged from 6.64% to 24.5.

Yield parameters

The yield attributes such as per plant pod number, pod weight, seed number, seed weight of blackgram genotypes decreased when water deficit stress was imposed during flowering stage but there was significant variation among genotypes. Under well watered condition, the per plant number of pods ranged from 22.0 (T-9) to 51.6 (PU-19) where as with water deficit stress it ranged from 11 (IC587751) to 45.6 (PU-19). Due to the water deficit stress, the decrease of pod number was from 34.1% to 22.46 % in black gram genotypes. The genotypes PU-19 and IC 398971 recorded highest number of pods per plant in well watered and water deficit stress. Hussian et al. (2013) also reported that pod number decreased under water deficit stress in blackgram, there was significant variation within genotypes.

Pod weight per plant also followed similar trend as pod number. The average percentage of reduction of pod weight was from 3.84 g/plant (IC 282009) to 58.52 g/plant (IC 587753). The pod weight of PU 19 was highest under control 14.75 g/plant as well as stress conditions 14.42 g/plant followed by IC 398971 (control 10.94 g/plant, stress 9.27 g/plant). However the genotype IC436610 though performed best in terms of pod weight (13.94 gpl^{-1}) under well watered condition, the genotypes recorded lower pod weight under water deficit conditions (4.19 gpl^{-1}) Dahanayake Nilanthi et al. (2014) reported that water deficit conditions at reproductive stage reduced pod weight in blackgram compared to control treatment. Water deficit stress significantly reduced number of seed/plant and average reduction of 35% was recorded with selected blackgram genotypes. The number of seeds per plant ranged from 69.67 (T-9) to 209 (PU-19) in well watered condition and under water deficit stress from 45.67 (IC587751) to 172 (PU-19). The genotype PU-19 performed better for per plant seed number under both in control (209) and water deficit stress (134) conditions. Hussain et al. (2015) also observed decreased seed number in chickpea under water deficit stress conditions with significant genotypic variability. Seed yield also recorded similar impact of water deficit stress as seed number and the average reduction of seed yield of genotypes was

Table 2. Physiological parameters of blackgram genotypes at two moisture levels and % reduction with water deficit stress

	Anet (μmol CO_2 m^{-2} s^{-1})			gs (cm s^{-1})			Tr (mmol m^{-2} s^{-1})			WUE (μmol CO_2/mmol H_2O)			SPAD Reading		
Genotype	Control	Stress	% Redn	Control	Stress	% Redn	Control	Stress	% Redn	Control	Stress	% Redn	Control	Stress	% Redn
IC 281987	31.2	20.8	33.3	0.6	0.3	53.2	13.6	9.7	28.5	2.3	2.1	6.7	48.5	40.7	16.1
IC 282009	26.7	15.7	41.2	0.8	0.4	52.0	14.9	8.6	42.3	1.8	1.8	-1.8	46.0	36.4	20.9
IC 343947	35.1	9.0	74.4	0.6	0.2	71.3	13.3	7.6	42.7	2.6	1.2	55.3	48.5	44.2	8.9
IC 343952	34.1	18.5	45.7	0.7	0.4	42.4	13.5	11.4	15.3	2.5	1.6	35.9	40.4	34.5	14.5
IC 398971	30.6	30.4	0.7	0.7	0.3	50.6	15.4	11.4	26.3	2.0	2.7	-34.9	39.8	34.1	14.3
IC 436519	35.3	15.7	55.6	0.6	0.2	65.5	12.6	7.8	38.5	2.8	2.0	27.8	49.1	39.0	20.6
IC 436610	29.7	21.7	26.9	0.7	0.2	75.7	14.3	6.8	52.6	2.1	3.2	-54.3	52.5	39.6	24.7
IC 436652	32.7	18.6	43.2	0.8	0.2	75.2	12.5	8.0	36.0	2.6	2.3	11.3	43.3	40.6	6.4
IC 436720	35.7	23.6	33.9	0.7	0.3	64.7	14.7	8.5	41.9	2.4	2.8	-13.7	51.5	35.2	31.6
IC 436753	24.7	15.6	36.7	0.6	0.2	71.4	12.5	7.4	40.9	2.0	2.1	-7.0	42.7	38.0	10.9
IC 519805	33.1	20.3	38.6	0.7	0.3	51.3	14.5	10.4	28.4	2.3	2.0	14.1	43.0	37.8	12.1
IC 587751	34.8	17.8	48.9	0.6	0.3	48.6	15.0	10.9	27.1	2.3	1.6	29.9	44.5	36.6	17.6
IC 587752	37.6	17.6	53.1	0.7	0.3	51.3	14.2	10.5	25.8	2.7	1.7	37.0	43.2	37.2	13.8
IC 587753	35.7	25.6	28.3	0.7	0.4	38.3	14.3	11.7	17.9	2.5	2.2	12.0	43.0	38.0	11.6
PU-19	31.2	23.3	46.7	0.6	0.2	68.1	13.1	7.4	43.4	2.4	2.2	5.9	53.9	37.8	29.9
LBG-20	31.3	25.5	18.7	0.5	0.4	23.2	12.6	11.4	9.3	2.5	2.2	10.4	43.8	42.5	3.0
T-9	30.9	25.6	17.0	0.7	0.4	46.1	15.7	12.3	21.3	2.0	2.1	-5.3	48.5	35.2	27.4
Mean	32.4	20.3	37.8	0.6	0.3	55.8	13.9	9.5	31.7	2.3	2.1	7.6	46.0	38.1	16.7
Min	24.7	9.0	0.7	0.5	0.2	23.2	12.5	6.8	9.3	1.8	1.2	-54.3	39.8	34.1	3.0
Max	37.6	30.4	74.4	0.8	0.4	75.7	15.7	12.3	52.6	2.8	3.2	55.3	53.9	44.2	31.6

% Redn: % of reduction; Anet: Net photosynthetic rate; gs: Stomatal conductance; Tr: Transpiration rate; WUE: Water use efficiency

Table 3. Mean values of yield parameters and % reduction with water deficit stress of seventeen blackgram genotypes

	Pod number			Seed number			Pod weight (g/pl)			Seed yield (g/pl)		
Genotype	Control	Stress	% Redn	Control	Stress	% Redn	Control	Stress	% Redn	Control	Stress	% Redn
IC 281987	41.7	27.0	35.2	156.0	84.7	45.7	12.1	7.3	39.5	7.5	3.8	49.3
IC 282009	37.7	33.0	12.4	119.0	115.0	3.4	9.2	8.0	13.4	5.2	5.0	3.8
IC 343947	46.0	19.3	58.0	191.7	66.0	65.6	12.5	5.0	60.1	5.1	3.1	39.3
IC 343952	27.0	15.0	44.4	102.7	75.0	26.9	6.1	5.3	13.0	4.0	3.1	23.0
IC 398971	35.7	33.3	6.6	139.0	134.0	3.6	10.9	9.3	15.2	6.4	6.0	6.4
IC 436519	32.3	21.0	35.1	118.3	73.7	37.7	8.4	6.4	23.9	5.5	3.5	36.5
IC 436610	42.7	20.0	53.1	170.3	65.3	61.6	13.9	4.2	69.9	4.0	2.5	36.8
IC 436652	35.0	14.3	59.0	122.7	57.7	53.0	8.5	4.9	43.0	4.8	2.8	41.9
IC 436720	25.3	23.3	7.9	96.0	87.7	8.7	8.0	7.0	13.1	4.9	4.1	15.6
IC 436753	26.0	24.0	7.7	81.0	77.7	4.1	6.4	5.2	19.2	3.8	2.9	24.0
IC 519805	34.0	30.0	11.8	134.0	102.0	23.9	9.3	6.7	27.8	4.9	4.4	9.4
IC587751	22.3	11.0	50.7	108.7	45.7	58.0	7.3	3.1	57.8	3.9	1.9	51.7
IC587752	33.7	14.7	56.4	158.0	53.7	66.0	11.2	3.8	66.0	4.3	2.3	46.1
IC 587753	33.7	14.5	56.9	120.3	65.5	45.6	7.8	3.5	55.6	4.6	1.9	58.5
PU-19	51.7	45.7	11.6	209.0	172.7	17.4	14.8	14.4	2.3	9.2	8.7	6.0
LBG-20	33.0	21.3	35.4	111.0	63.0	43.2	8.3	4.2	49.8	4.7	2.1	55.1
T-9	22.0	14.3	34.8	69.7	46.7	33.0	6.1	2.5	58.0	3.1	1.6	47.1
Mean	34.10	22.46	33.94	129.84	81.52	35.15	9.466	5.922	36.926	5.05	3.51	32.39
Min	22.00	11.00	6.55	69.67	45.67	3.36	6.07	2.55	2.25	3.07	1.63	3.84
Max	51.67	45.67	59.05	209.00	172.67	66.03	14.75	14.42	69.92	9.23	8.68	58.52

% Redn: % of reduction

32.4%. The genotype PU-19 performed best under control (9.23 gpl^{-1}) as well as water deficit conditions (8.68 gpl^{-1}) with lowest reduction (6%). Our results are align with Baroowa et al. (2012) where reduced seed yield was observed under moisture stress conditions in both blackgram and green gram.

Conclusion

Water deficit stress at flowering stage of blackgram significantly affected both physiological and yield contributing parameters. Based on the results it can be concluded that blackgram genotype IC398971 recorded better physiological parameters under well watered condition and recorded less reduction in Anet, SPAD readings and improved WUE under water deficit stress conditions revealing its ability to tolerate water deficit. The genotype also recorded less reduction in yield parameters with water deficit stress. While among the genotypes studied, PU-19 recorded highest pod number, seed number, pod weight and seed yield under both moisture levels showing its stability in performance in stressful environments. So, these physiological and yield parameters help to screen the genotypes to water deficit stress and is useful in selecting genotypes with tolerant mechanism.

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