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Growth Indices and Yield Attributes of Blackgram (*Vigna mungo* (L.) Hepper) Genotypes under High Temperature Stress at Flowering Stage

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Abstract High temperature stress during flowering stages is becoming a serious limitation to pulse production. Most of the areas are experience unexpected warmer environments and temperature variability due to climate change. The main objective of this study is to screen blackgram genotypes for high temperature tolerance based on the morphological traits, yield and yield components. Twenty four genotypes of blackgram were evaluated for tolerance to high temperature and Yellow Mosaic Virus (YMV) in the field under irrigated condition. The flowering and anthesis of genotypes were coincided with high temperature regime of more than 38+2°C and continued for more than ten days. Growth parameters observations were recorded at different growth stages viz., 10, 20, 30, 40, 55 DAS and at harvest by selecting ten representative samples at randomly from each replication. In this present study it was clearly observed that VBG-07-001 and VBG-06-002 possessed higher growth and yield attributes indicating the genotypic preference over the other genotypes.

Keywords Blackgram, High temperature, Growth, Yield attributes, Flowering stage.

Introduction

Blackgram (*Vigna mungo* (L.) Hepper) is a tropical leguminous plant, which belongs to the Asiatic *Vigna* species. India is the largest producer and consumer of blackgram in the world. Pulses are major sources of proteins among the vegetarians in India and it contains 22–24% protein which is almost twice the protein in wheat and thrice that of rice. Pulses provide significant nutritional benefits and reduces several non-communicable diseases such as colon cancer and cardiovascular diseases [1].

The fourth assessment report from Inter Governmental Panel on Climate Change (IPCC) assessed there is an increase in global mean temperatures between 1.6°C and 6.9°C by the end of the 21st century. The

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Table 1. Details of genotypes used in this study with source.

V. No	Genotypes	Source/Origin	V. No	Genotypes	Source/Origin
V_1	VBG-08-004	NPRC, Vamban	V_{16}	VBG-04-003	NPRC, Vamban
V_2	VBG-07-006	NPRC, Vamban	V_{17}	VBG-04-010	NPRC, Vamban
V_3	VBG-06-002	NPRC, Vamban	V_{18}	VBG-06-003	NPRC, Vamban
V_4	VBG-08-002	NPRC, Vamban	V_{19}	VBG-07-009	NPRC, Vamban
V_5	VBG-08-001	NPRC, Vamban	V_{20}	VBG-09-005	NPRC, Vamban
V_6	VBG-06-005	NPRC, Vamban	V_{21}	VBG-10-008	NPRC, Vamban
V_7	VBG-08-003	NPRC, Vamban	V_{22}	VBG-10-024	NPRC, Vamban
V_8	VBG-07-001	NPRC, Vamban	V_{23}	VBN-6	NPRC, Vamban
V_9	VBG-04-005	NPRC, Vamban	V_{24}	VBN-7	NPRC, Vamban
V_{10}	VBG-06-009	NPRC, Vamban	V_{25}	CO-6	TNAU, Coimbatore
V_{11}	VBG-07-008	NPRC, Vamban	V_{26}	COBG-11-02	TNAU, Coimbatore\
V_{12}	VBG-08-005	NPRC, Vamban	V_{27}	COBG-11-03	TNAU, Coimbatore
V_{13}	VBG-07-007	NPRC, Vamban	V_{28}	COBG-10-05	TNAU, Coimbatore
V_{14}	VBG-06-010	NPRC, Vamban	V_{29}	COBG-10-06	TNAU, Coimbatore
V_{15}	VBG-07-004	NPRC, Vamban	V_{30}	COBG-759	TNAU, Coimbatore

most worrying part of the prediction is the estimated increase in winter and summer temperatures by 3.2°C and 2.2°C respectively in 2050 [2]. The predicted changes in temperature, rainfall and extreme weather events are likely to affect the potential production of pulses [3]. Blackgram is a short duration crop (65–75 days) the further reduction in crop duration will amount to lower yield per unit area [4]. Therfore, it is important to select genotypes having tolerance mechanism for temperature, so that the future challenge on global warming can be addressed. With this view the present investigation is attempted to screen blackgram genotypes for high temperature tolerance based on the morpho physiological traits, yield and yield components.

Materials and Methods

Initially twenty four blackgram genotypes were screened under field condition during October to December to rule out any susceptibility towards YMV under natural field condition. Out of 24 genotypes, eleven genotypes were discarded based on the YMV incidence. Since the experiment was conducted at Coimbatore, six promising Coimbatore cultures under pipe line were included for further experimentation. Field trails were initiated with 19 genotypes under irrigated condition during March–May in Wetland farm (11°N latitude, 77° E longitude; 426.7 MSL), of TNAU for screening for high temperature tolerance. The details of genotypes used in this study with

Table 2. List of blackgram genotypes evaluated for Yellow Mosaic Virus (YMV) incidence in the field condition.

Sl. No.	V. No.	Genotype	Reaction to YMV
1.	V_1	VBG-04-003	No YMV
2.	V_2	VBG-04-005	No YMV
3.	V_3	VBG-04-010	YMV (25%)
4.	V_4	VBG-06-002	No YMV
5.	V_5	VBG-06-003	No YMV
6.	V_6	VBG-06-005	No YMV
7.	V_7	VBG-06-007	YMV (5%)
8.	V_8	VBG-06-009	No YMV
9.	V_9	VBG-06-010	No YMV
10.	V_{10}	VBG-07-001	No YMV
11.	V_{11}	VBG-07-004	YMV (3%)
12.	V_{12}	VBG-07-006	YMV (10%)
13.	V_{13}	VBG-07-008	YMV (5%)
14.	V_{14}	VBG-07-009	YMV (5%)
15.	V_{15}	VBG-08-001	YMV (2%)
16.	V_{16}	VBG-08-002	Heavy YMV
17.	V_{17}	VBG-08-003	No YMV
18.	V_{18}	VBG-08-004	YMV (2%)
19.	V_{19}	VBG-08-005	YMV (2%)
20.	V_{20}	VBG-09-005	YMV (1%)
21.	V_{21}	VBG-10-008	No YMV
22.	V_{22}	VBG-10-024	No YMV
23.	V_{23}	VBN-6	No YMV
24.	V_{24}	VBN-7	No YMV

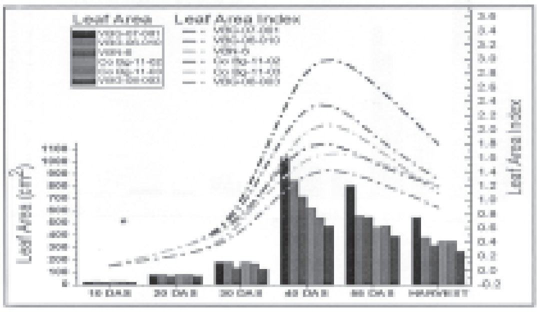

Fig. 1. Impact of high temperature at flowering on Leaf Area (LA) (cm^2) and Leaf Area Index (LAI) in blackgram genotypes under field condition.

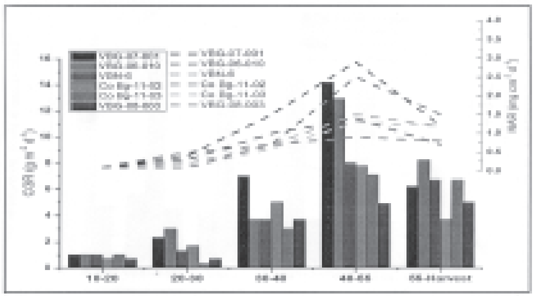

Fig. 2. Impact of high temperature at flowering on Crop Growth Rate (CGR) ($g\ m^2d^{-1}$) and Net Assimilation Rate (NAR) ($mg\ cm^2d^{-1}$) in blackgram genotypes under field condition.

source are furnished in Table 1.

Sowing was done on the ridges and furrows with row and plant spacing of 30×10 cm and a plot size of 5×4 m. Each genotype was replicated thrice in a randomized block design. The biometric characters were recorded at different growth stages viz., 10, 20, 30, 40, 55 DAS and at harvest by selecting ten representative samples at randomly from each replication. The methods followed in recording the observations are described below.

Leaf area

Leaf Area per plant was measured using a Leaf Area Meter (LICOR, Model LI 3000) and expressed as cm^2 $plant^{-1}$.

Leaf area index (LAI)

The Leaf Area Index was calculated by employing the formula of Williams [5]. LAI=Leaf area per plant/ Ground area occupied by the plant.

Leaf area duration (LAD)

Leaf Area Duration was determined using the formula of Power et al. [6] and expressed in days. $LAD=(L_1 + L_2/2)*(t_2 - t_1)$.

Net assimilation rate (NAR)

It is the rate of increase of leaf dry weight per unit area of leaf per unit time [5] and expressed as mg cm^{-2} day^{-1}, $NAR = (Loge\ L_2 - Loge\ L_1/L_2 - L_1)*(W_2 - W_1/T_2 - T_1)$.

Crop growth rate (CGR)

CGR is measure of the rate of increase of dry weight per unit land area per unit time. Watson [7, 8] suggested the following formula and expressed as g m^{-2} day^{-1}. $CGR = (W_2 - W_1)/P\ (t_2 - t_1)$.

Total dry matter production (TDMP)

For estimating total dry matter production, the ten plants were randomly pulled out with root system intact at harvest stage in each genotype and weighed after drying the plants at 80^oC for 24 h. The mean values were worked out and expressed in g $plan^{-1}$.

Yield and yield components

The important components contributing to the yield potential of the crop were recorded from the commencement of flowering to the harvest of the crop. Different yield parameters recorded in the present study are indicated below.

Table 3. Impact of high temperature at flowering on Leaf Area Duration (LAD) (days) in blackgram genotypes under field condition.

Sl. No.	V. No.	Genotypes	Days after sowing 10-20	20-30	30-40	40-55	Harvest
1.	V_1	VBG-04-003	1.6	4.2	15.9	33.5	31.4
2.	V_2	VBG-04-005	1.2	3.5	15.1	35.6	37.9
3.	V_4	VBG-06-002	1.6	4.4	16.8	35.7	34.3
4.	V_5	VBG-06-003	1.6	4.1	15.2	33.2	31.1
5.	V_6	VBG-06-005	1.6	3.6	15.8	36.2	38.2
6.	V_8	VBG-06-009	1.5	3.5	12.2	26.1	25.9
7.	V_9	VBG-06-010	1.7	4.3	17.1	35.1	31.3
8.	V_{10}	VBG-07-001	1.7	4.3	20.3	46.0	45.0
9.	V_{17}	VBG-08-003	1.5	3.3	10.1	21.7	22.0
10.	V_{21}	VBG-10-008	1.5	3.8	15.8	35.4	34.1
11.	V_{22}	VBG-10-024	1.3	3.6	12.7	27.2	25.1
12.	V_{23}	VBN-6	1.5	3.4	14.1	31.5	28.8
13.	V_{24}	VBN-7	1.6	4.1	14.6	33.0	33.7
14.	V_{25}	CO-6	1.6	3.5	10.6	21.3	21.7
15.	V_{26}	COBG-11-02	1.7	4.4	13.4	27.1	27.1
16.	V_{27}	COBG-11-03	1.6	4.1	11.9	25.5	27.6
17.	V_{28}	COBG-10-05	1.7	4.6	15.0	30.6	29.2
18.	V_{29}	COBG-10-06	1.6	4.0	13.1	27.8	27.0
19.	V_{30}	COBG-759	1.6	4.0	15.9	32.3	27.1
	Mean		1.6	3.9	14.5	31.3	30.4
	SEd		0.017	0.054	0.166	0.440	0.445
	CD (p=0.05)		0.034*	0.108*	0.333*	0.884*	0.892*

Number of flowers per plant

A total of 10 plants were randomly selected from each genotype and tagged for daily count of opened flowers on main stem as well as on the branches. Flower count began from the date of opening of first flower and continued after every 12 h i.e. at 6.00 and 18.00 h daily until flowering ceased for first flush. The total number of flowers and number of clusters per plant produced during flowering period was recorded and the mean values expressed in numbers.

Number of pods per plant and number of seeds per pod

The number of pods produced in each plant and number of seeds produced in each pod was taken randomly from plants in each genotype. The average was calculated and expressed in numbers.

Yield per hectare

Yield of each net plot was recorded separately and the mean yield was expressed in kilogram per hectare.

Results and Discussion

Impact of high temperature at flowering stage in blackgram genotypes under field condition

Twenty four genotypes of blackgram were evaluated for tolerance to high temperature and Yellow Mosaic Virus (YMV) in the field under irrigated condition (Table 2). YMV is a serious disorder causing not only yield reduction and also further proliferation and dissemination of the disease thus causes serious spread.

Growth attributes

Leaf area (cm^2 plant^{-1})

In crop like pulses, the leaf area development and maintenance is an important parameter indicating the genotyping superiority. In general the Leaf Area

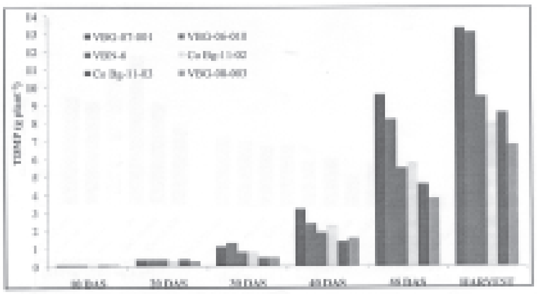

Fig. 3. Impact of high temperature at flowering on Total Dry Matter Production (TDMP) (g plant^{-1}) in blackgram genotypes under field condition.

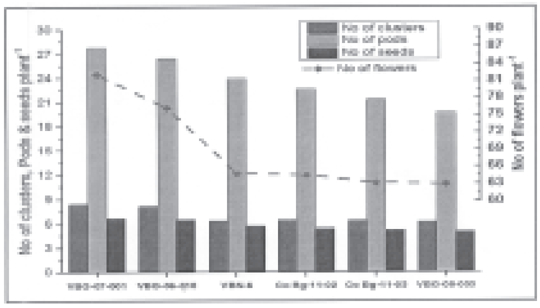

Fig. 4. Impact of high temperature at flowering on yield components of blackgram genotypes under field condition.

showed gradual increase from the beginning upto 40 DAS and there on slight decline was observed till harvest (Fig. 1). Highest Leaf Area of 1034 cm^2 was recorded in the genotype VBG-07-001 followed by VBG-06-002 at 40 DAS. Even at 55 DAS upto harvest VBG-07-001 and VBG-06-002 maintained significantly. Therefore, the present investigation is in conformity with the finding of Shah and Paulson [9] who have clearly showed leaf area is an indicative character for stress studies.

Leaf area index (LAI)

Leaf Area Index was observed to be following the same trend as that of the Leaf Area. The mean Leaf Area Index ranged from 0.1 to 2.4 irrespective of the genotypes (Fig. 1). The highest Leaf Area Index of 3.4 and 2.7 was recorded in VBG-07-001 at 40 and 55 days after sowing followed by 2.7 and 2.0 in VBG-06-002 for the same period. Chauhan et al. [10] have reported that LAI would be used as a measure of high yield and showed that this character is associated with abiotic stress tolerance.

Leaf area duration (LAD: days)

Leaf Area Duration refers to the maintenance of photosynthetic area with reference to crop duration. The mean LAD ranged from 1.6 to 31.3 irrespective of the genotypes (Table 3). The highest LAD was observed in VBG-07-001 with 46 days followed by VBG-06-002 with 35.7 days during 40–55 DAS. The lowest LAD was recorded in CO-6 with 21.3 days at 40–55 DAS. Araus et al. [11] have already emphasized that higher LAD is an indication of high yield besides showing tolerance towards abiotic stresses.

Net assimilation rate
(NAR: mg cm^{-2} d^{-1})

The Net Assimilation Rate is a measure of net photosynthesis of leaves in a crop community. It was observed that NAR gradually showed an increasing trend from the beginning upto 55 DAS and there on slight decline was noticed towards harvest (Fig. 2). The genotypes VBG-07-001 showed the highest mean NAR of 1.2 mg cm^{-2} d^{-1} irrespective of the stages and the lowest value was showed by VBG-08-003 irrespective of the stages with 0.5 NAR (mg cm^{-2} d^{-1}). Maintaining higher NAR values even uo to flowering showed positive relationship with that of the yield [12].

Crop growth rate
(CGR: g m^{-2} d^{-1})

Highest mean CGR of 8.4 g m^{-2} d^{-1} recorded at flowering irrespective of the genotypes. Among the 19 blackgram genotypes study the highest mean CGR g m^{-2} d^{-1} was recorded in VBG-07-001 with 6.1 g m^{-2} d^{-1} followed by VBG-06-002 with 5.7 values (Fig. 3). Hence, the present study is in conformity with the reports of Shibles and Weber [13] who have emphasized the importance of CGR in varietal response.

Table 4. Grouping of blackgram genotypes based on growth parameters at flowering under field condition.

Sl. No.	Parameters and range	Tolerant	Moderately tolerant	Susceptible
1	Leaf Area (cm^2)	VBG-07-001	VBG-06-003	VBG-10-024
		VBG-06-010	VBN-6	VBG-06-009
	T - 750 to < 1050	VBG-06-002	VBN-7	CO-6
	MT - 650 to 750	VBG-06-005	COBG-10-05	COBG-11-03
	S - 450 to 650	VBG-10-008	COBG-11-02	VBG-08-003
		COBG-759	COBG-10-06	
		VBG-04-003		
		VBG-04-005		
2	Leaf Area Index	VBG-07-001	VBG-04-005	VBG-06-009
		VBG--6-010	VBG-06-003	VBG-10-024
	T - 2.6 to < 3.5	VBG-06-002	VBN-6	CO-6
	MT - 2,1 to 2.5	VBG-06-005	VBN-7	COBG-11-03
	S - 1.0 to 2.0	VBG-04-003	COBG-11-02	VBG-08-003
		VBG-10-008	COBG-10-05	
		COBG-759	COBG-10-06	
3	Leaf Area Duration (days)	VBG-07-001	VBG-06-03	COBG-10-06
		VBG-06-005	VBN-7	VBG-10-024
	T - 35 to < 45	VBG-06-002	COBG-759	COBG-11-02
	MT - 30 to 35	VBG-04-005	VBN-6	VBG-06-009
	S - 15 to 30	VBG-10-008	COBG-10-05	COBG-11-03
		VBG-06-010		VBG-08-003
		VBG-04-003		CO-6
4	Net Assimilation Rate (mg cm^2 day^{-1})	VBG-07-001	VBG-06-003	COBG-11-03
		VBG-06-010	VBN-6	VBG-10-024
		VBG-06-002	VBN-7	CO-6
	T - 1.6 to < 2.9	VBG-04-005	VBG-04-003	COBG-759
	MT - 1.4 to 1.5	VBG-06-005	COBG-11-02	VBG-08-003
	S - 1.0 to 1.3	VBG-06-009	COBG-10-05	
		VBG-10-008	COBG-10-06	
5	Crop Growth Rate (g m^2 day^{-1})	VBG-07-001	VBN-6	COBG-10-06
		VBG-06-010	VBN-7	COBG-11-03
		VBG-06-002	COBG-11-02	CO-6
	T - 8.1 to < 15	VBG-04-005	VBG-04-003	COBG-759
	MT - 7.6 to 8.0	VBG-06-005	VBG-06-003	VBG-08-003
	S - 4.0 to 7.5	VBG-06-009	VBG-10-024	
		VBG-10-008	COBG-10-05	
6	Total Dry Matter Production	VBG-07-001	VBG-06-005	VBG-10-024
	(g $plant^{-1}$)	VBG-06-002	VBG-04-005	COBG-11-03
		VBG-06-010	VBG-04-003	CO-6
	T - 10 to < 13	VBG-10-008	VBN-6	VBG-06-009
	MT - 9 to 10	VBN-7	COBG-10-05	COBG-11-02
	S - 6 to 9	COBG-759	COBG-10-06	VBG-08-003
			VBG-06-003	

Total dry matter production
(TDMP) (g $plant^{-1}$)

The impact of high temperature showed a short response with reference to genotypic variability. The mean TDMP ranged from 2.2 in VBG-08-003 to 4.6 in VBG-07-001 irrespective of the crop phenology (Fig. 3). Considering the growth stage, the highest TDMP was recorded at harvest and VBG-07-001 registered 13.3 g followed by VBG-06-002 and VBG-06-010 with 13.1 g $plant^{-1}$.

Based on the growth analytical parameters an attempt has been made to differentiate genotypic vari-

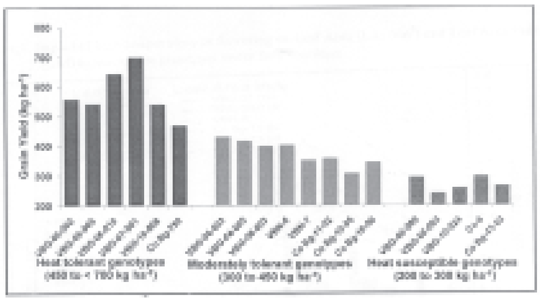

Fig. 5. Impact of high temperature at flowering on yield of blackgram genotypes under field condition.

ability such as tolerant, moderately tolerant and susceptible for atmospheric heat (Fig. 6). Abiralam et al. [14] have already reported that TDMP is sensitive especially when the crop is subjected to high temperature at flowering.

Yield and yield components

The number of flowers per plant ranged from 82.2 to 63.0 in VBG-07-001 and VBG-08-003 respectively irrespective of genotypes (Fig. 4). It was seen that the total number of flowers produced among the genotypes did not show any significant differences. However VBG-07-001 and VBG-06-002 showed a slight increase in the number of flowers produced.

Among the yield components the number of clusters per plant, number of pods per cluster showed significant differences among the genotypes. Among the genotypes, six genotypes namely VBG-06-002, VBG-06-005, VBG-06-010, VBG-07-001, VBG-10-008 and COBG-759 registered highest yield components when compared to rest of the genotypes. Among the six genotypes VBG-07-001 followed by VBG-06-010 shows the highest cluster and number of pods per plant. In case of the number of seeds per pod, there was no significant difference among the genotypes.

The grain yield ranged from 241.30 kg to 699.4 kg/ha in VBG-08-003 and VBG-07-001 respectively. This wide ranged yield variation with reference to genotype and atmospheric high temperature interaction prompted to categorize the genotypes into heat tolerant, moderately heat tolerant and heat susceptible groups based on the yielding potential (Table 4). Grouping was done in the category when the crop registers 200-300 kg/ha as susceptible genotypes, from 300–450 kg/ha as moderately and when the crop register more than 450 kg/ha falls in the category of high temperature genotypes. Accordingly six genotypes VBG-06-002, VBG-06-005, VBG-06-010, VBG-07-001, VBG-10-008 and COBG-759 falls in the categories of heat tolerant group and deserve further evaluation (Fig. 5). Also, Mary [15] demonstrated that tolerance genotype will possess the stable or least reduction in yield response to heat stress in soybean.

In the present field experiment various yield components such as the total number of flowers produced, number of clusters per plant, number of pods per plant and yield were recorded under the influence of high temperature coinciding with flowering. Vijayaraghavan et al. [16] have reported that high temperature invariably has a direct influence in flowering abscission in blackgram.

Conclusion

Therefore, we have identified ten blackgram genotypes six from heat tolerant group and four from moderately tolerant for future evaluation in other breeding programs. Therefore, we have identified ten blackgram genotypes six from heat tolerant group and four from moderately tolerant for future evaluation in other breeding programs.

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