EFFECT OF HIGH TEMPERATURE STRESS ON PHOTOSYNTHETIC PIGMENTS, DRY MATTER PARTITIONING AND YIELD OF BLACKGRAM (*Vigna mungo* L.) GENOTYPES AT POD FORMATION STAGE

Abstract

A field experiment was conducted at College farm, Agricultural College, Bapatla, Acharya N.G. Ranga Agricultural University during summer, 2022 and 2023 to study the impact of high temperature stress on photosynthetic pigments, dry matter partitioning and yield of blackgram genotypes at pod formation stage. The experiment was carried out in randomized block design with two replications. Among the thirty blackgram genotypes screened for their tolerance to high temperature stress at pod formation stage, the genotype, TBG-129, LBG-1015 and PU-1804 were found to withstand high temperature stress and maintain higher total chlorophyll content, carotenoids content, dry matter partitioning and higher seed yield per plant indicating tolerance to high temperature stress.Theseblackgram genotypes can be further used as donors in the pulse breeding program for development of heat resilent varieties.

Key words: Blackgram, High temperature stress, Pod formation stage

Introduction

Blackgram is an tropical leguminous crop which is grown in all seasons all over the India. It has high nutritive value and consists of high content of protein, vitamins and minerals (Sujatha *et al*., 2018). India currently represents the largest producer of blackgramwhichaccounts for more than 70% of global production. In India, blackgramis cultivated in an area of 46.33 lakh hectares with an annual production of 27.75 lakhtonnes and productivity of 4.24 lakh tonnes and 1059 kg ha^{-1} (Ministry of Agriculture, 2021-22). To meet the demand of growing population, improvement in pulse production is required.

The major constraints in the blackgram production are abiotic stresses, abrupt climatic changes, emergence of new insect-pests and diseases, and in soil deficiency of secondary and micronutrients (Ali and Gupta, 2012). In particular, heat stress caused by elevated temperatures is strongly affecting plant growth and development, which leads to drastic reduction in the economic yield (Partheeban and Vijayaraghavan, 2017). In the present climate change scenario, the rise in temperature is threatening the global food security impacting pulse production adversely. Global air temperature is predicted to rise by 0.2 °C per decade, which will lead to 1.8–4.0 °C higher temperatures than the current level by 2100 (Hasanuzzaman*et al*., 2013). Blackgram being a thermosensitive crop its yield is highly sensitive to high temperatures exceeding 35 ℃(Anitha *et al.*, 2015). Among the various crop phenophases, reproductive or seed filling stages are reported to be extremely sensitive to even few degrees rise in temperatures leading marked reduction in yield potential.

Information regarding the physiological responses of blackgram genotypes to heat stress during pod formation stage is rarely available. Among the physiological traits, chlorophyll content is one of the key trait for selecting photosynthetically efficient genotypes under heat stress conditions (Chaudhary *et al.*, 2022).Many varieties ofblackgram have been released and are being cultivated worldwide. Some of the prereleases are still under different stages of testing. However, continuous evaluation is a must for identifying the potentiality of genotypes under high temperature conditions. Hence, the present investigation was carried out to identify elite blackgram genotypes that can withstand high temperature stress at pod formation stage.

Materials and methods

Blackgram genotypes (30) were procured from AICRIP (pulses), Regional Agricultural Research Station (RARS), Lam, Guntur, Andhra Pradesh, India. The 27 tolerant and 3 susceptible genotypes selected from TIR technique were further assessed for physiological traits under natural high temperature conditions during summer 2022 and 23 at College Farm, Agricultural College, Bapatla, Acharya N.G Ranga Agricultural University. The experimental site was geographically located at 15°54’ N latitude and 80°47’ E longitude and at an altitude of 5.49 m above mean sea level (MSL), which is about 8 km away from the Bay of Bengal in the Krishna Agro-Climatic zone of Andhra Pradesh, India. The weather parameters during cropping season were presented in (Fig. 1). Observations such as chlorophyll a, chlorophyll b, total chlorophyll, carotenoids,dry matter partitioning (Leaf Dry Matter (LDM), Stem Dry Matter (SDM), Reproductive parts Dry Matter (RDM) and Total Dry Matter (TDM))and yield attributes such as number of pods per plant (NPP) and seed yield per plant (SYP) were recorded at pod formation stageThe mean maximum temperature during first season (summer, 2022) at pod formation stage, ranged from 35.0 to 37.7 ℃. During second season (summer, 2023) at pod formation stage, it was ranged from 37.7 to 39.7 ℃.

Photosynthetic pigments

0.1g of fresh leaf material was placed in a test tube and was heated in a water bath for 1 hr at 65 ℃ and after heating, 10 mL of DMSO was added to it. Keep both treated and untreated samples for overnight. Chlorophyll extracted into DMSO solution was collected from test tubes and the absorbance of chlorophyll extract of heat treated samples was measured with a spectrophotometer at 652nm and untreated samples at 652, 663, 645, 480 and 510 nm.

$$\text{Total chlorophyll (mg g}^{-1}\text{)} = \frac{\mathrm{D}.652 \times 1000}{34.5} \times \frac{\mathrm{V}}{1000 \times \mathrm{W}}$$

$$\text{Chlorophyll a} = 12.7\ (\mathrm{A}663) - 2.69\ (\mathrm{A}645) \times \frac{\mathrm{V}}{1000 \times \mathrm{W}}$$

$$\text{Chlorophyll b} = 22.9\ (\mathrm{A}645) - 4.68\ (\mathrm{A}663) \times \frac{\mathrm{V}}{1000 \times \mathrm{W}}$$

$$\text{Carotenoid content (mg g}^{-1}\text{)} = 7.6\ (\mathrm{D}480) - 1.49\ (\mathrm{D}510) \times \frac{\mathrm{V}}{1000 \times \mathrm{W}}$$

Dry matter partitioning (g plant^{-1})

The total biomass was estimated from the five adjacent plants sampled from each treatment in two replications and then separated into leaves, stems and pods. The plant parts were dried to a constant weight in hot-air-oven at 80 ℃ for two days and the dry weights were recorded and expressed in g plant^{-1}.

Yield and yield attributes

Yield parameters such as Number of pods per plant (NPP) and seed yield per plant (SYP) were recorded at harvest during both the years.

Statistical analysis

The data were analyzed statistically by following analysis of variance technique suggested by Panse and Sukhatme, (1984) for Randomized Block Design (RBD). The statistical hypothesis of equalities of treatment means was tested by F-test at 1 to 5% per cent level of significance.

Results and Discussion

Photosynthetic pigments

The data pertaining to photosynthetic pigments in the blackgram genotypes were recorded at pod formation stageduring summer, 2022 and 2023 and the pooled data were presented in the Table 1. Pooled data of two seasons revealed that there was significant variation among the all the genotypes with respect to chlorophyll a content. Chlorophyll a content ranged between 0.44 to 0.67mg g^{-1}.Maximum chlorophyll a content was recorded in TBG-141 (0.67 mg g^{-1}) followed by GBG-1 (0.61 mg g^{-1})and TBG-129 (0.60 mg g^{-1}) whereas minimum chlorophyll a content was recorded in LBG-1023 (0.44 mg g^{-1}) followed by TBG-125 (0.45 mg g^{-1}) and LBG-1006 (0.48 mg g^{-1}). Chlorophyll b content ranged between0.23 and 0.49 mg g^{-1}. It was significantly higher in TBG-129 (0.49 mg g^{-1}) followed by LBG-1015 (0.46mg g^{-1}) and LBG-995, PU-31 (0.45 mg g^{-1}) while, lower in LBG-1023 (0.23 mg g^{-1}) followed by TBG-125 (0.25 mg g^{-1}). This increase in the chlorophyll a and chlorophyll b content might be due to increase in the content of PS I and PS II subunits, which might have protected the chl a/b proteins from proteosomal degradation thereby maintaining high chl a and b content even under stress conditions (Shan *et al.*, 2018).

Heat stress significantly affected the total chlorophyll content with mean values ranging from 0.67 to 1.06 mg g^{-1}. Significantly higher total chlorophyll content was recorded in TBG-129 (1.06 mg g^{-1}) followed by GBG-1 (1.03 mg g^{-1}), LBG-1015 (1.02 mg g^{-1})and TBG-141 (1.00mg g^{-1})while, lesser total chlorophyll content was recorded inLBG-1023 (0.67 mg g^{-1}) andTBG-125 (0.70 mg g^{-1}). This reduction in photosynthetic pigments with increase in temperature might be due to oxidative damage caused by outburst of ROS and inhibition of chlorophyll biosynthesis. Similar findings of higher levels of chlorophyll content in the thermotolerant chickpea genotypes under heat stress conditions were previously reported by Devi *et al.* (2022). Our results also concur with the published reports of Jincy *et al*. (2022) in greengram and Chaudhary *et al.* (2022) in blackgram.

Carotenoid content varied significantly among the genotypes with mean values of 0.48 and 0.80 mg g^{-1}f.wt. Higher carotenoid content was recorded in TBG-129 (0.80 mg g^{-1}) followed by PU-31 (0.77 mg g^{-1}), LBG-1015 and LBG-995 (0.75 mg g^{-1})whereas, lesser carotenoid content was recorded in LBG-1009 (0.48 mg g^{-1}) followed by LBG-918 (0.49 mg g^{-1}). Carotenoids act as molecular antioxidants in cells by scavenging singlet oxygen (Knox and Dodge, 1985). They also act as protectors of chloroplast pigments and membrane structure by quenching triplet chlorophyll and removing oxygen from excited chlorophyll oxygen complex (Young, 1991), thereby provide protection against damage due to high temperature stress.Our results are in accordance with the published reports of Sharma *et al.* (2022) in fieldpea.

Dry matter partitioning(g $plant^{-1}$)

The data pertaining to dry matter production and partitioning in the blackgram genotypes were recorded at pod formation stage during summer, 2022 and 2023 and the pooled data were presented in the Fig. 2.Pooled data of two seasons revealed that there was significant variation among the all the genotypes with respect to dry matter production and partitioning. LDM ranged from 1.90 to 3.09 g $plant^{-1}$. Higher LDM was recorded in TBG-129 (3.09 g $plant^{-1}$) which was at par with LBG-989 (3.09 g $plant^{-1}$) andLBG-904 (3.02 g $plant^{-1}$)while, lower in TBG-125 (1.90 g $plant^{-1}$) followed by LBG-1023 (2.04 g $plant^{-1}$).

SDM ranged from 1.09 to 1.80 g $plant^{-1}$. Higher SDM was recorded in LBG-989 (1.80 g $plant^{-1}$) which was at par with TBG-129 (1.76 g $plant^{-1}$), VBN-8 (1.72 g $plant^{-1}$)andLBG-1015 (1.70 g $plant^{-1}$)while, lower in TBG-125 (1.09 g $plant^{-1}$) followed by LBG-1023 (1.22 g $plant^{-1}$). RDM ranged from 0.97 to 2.52 g $plant^{-1}$. Higher RDM was recorded in TBG-129 (2.52 g $plant^{-1}$) followed by PU-31 (2.44 g $plant^{-1}$), PU-1804 and LBG-1015 (2.36 g $plant^{-1}$) while, it was lower in TBG-125 (0.97 g $plant^{-1}$) which was at par with LBG-1023 (1.11 g $plant^{-1}$).TDM ranged from 3.96 to 7.37 g $plant^{-1}$. Higher TDM accumulation was recorded in TBG-129 (7.37 g $plant^{-1}$)which was at par with LBG-1015 (7.06 g $plant^{-1}$) andPU-1804 (6.82 g $plant^{-1}$) while, it was lower in TBG-125 (3.96 g $plant^{-1}$) followed by LBG-1023 (1.22 g $plant^{-1}$). Our results corroborate with the findings of Kumar *et al.* (2013) in chickpea who reported the similar decline in total biomass production in the heat sensitive genotypes.

Yield and yield attributes

Pooled data of two seasons revealed that there was significant variation among the all the genotypes with respect to yield and yield attributes (Fig 3 & 4). NPP ranged from 3.8 to 21.5. The total NPP was higher in LBG-1015 (21.5) followed by PU-1804 (20.2), TBG-129 (19.9) and TBG-104 (19.8), whereas it was lower in TBG-125 (3.8) followed by LBG-1023 (4.7). The major reason for reduced yields due to heat stress was failure to set pods at high temperatures, especially by the heat sensitive genotypes. Our results agree with the published reports of Haritha (2020) who reported higher number of pods in thermotolerant genotypes.

SYP ranged from 1.0 to 4.3g plant^{-1}. SYP was higher in LBG-1015 (4.3 g plant^{-1}) followed by PU-1804 and TBG-129 (4.1 g plant^{-1}) whereas, TBG-125 (1.0 g plant^{-1}) recorded lower SYP which was at par with LBG-999, LBG-1023 (1.1 g plant^{-1}). Reduction in seed yield of sensitive genotypes might be due to triggered flower abortion, pollen and ovule dysfunction which resulted in failure of fertilization, affecting seed filling, and ultimately reduced the seed yield. Our results agree with the findings of Subrahmanyam and Rathore (1994) who reported that high temperature during reproductive stage in mustard significantly inhibited the import of photosynthates by both upper and lower pods of terminal receme, and thereby reduced the sink strength.

Conclusion

Genetic variability in various physiological and yield traits was assessed over 2 years in 30 blackgram genotypes grown under heat stress conditions during pod formation stage. The genotypes TBG-125 and LBG-1023 recorded lesser seed yield per plant indicating susceptibility to high temperature stress whereas, the genotypes TBG-129, LBG-1015 and PU-1804 recorded higher seed yield per plant indicating tolerance to high temperatures. The higher seed yield in these genotypes under high temperature stress conditions might be due to higher retention of photosynthetic pigments and higher dry matter partitioning. The tolerant genotypes identified in the present study can be further assessed for reproductive and biochemical efficiency traits under heat stress conditions for confirming their tolerance. Moreover, these genotypes should be tested across multilocations for confirming their tolerance to high temperature stress.

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Table 1 Effect of high temperature stress on photosynthetic pigments of blackgram genotypes at pod formation stage (pooled data)

S.No	Genotypes	Photosynthetic Pigments			
		Chl a (mg g^{-1}fwt)	Chl b (mg g^{-1}fwt)	Total Chlorophyll (mg g^{-1}fwt)	Carotenoids (mg g^{-1}fwt)
1	LBG-1016	0.57	0.35	0.92	0.63
2	LBG-1004	0.54	0.38	0.92	0.71
3	LBG-752	0.53	0.30	0.83	0.56
4	TBG-129	0.60	0.49	1.09	0.80
5	PU-1804	0.55	0.42	0.97	0.73
6	LBG-1015	0.55	0.46	1.02	0.75
7	LBG-918	0.49	0.34	0.82	0.49
8	LBG-997	0.54	0.35	0.89	0.61
9	PUSA B-58	0.57	0.36	0.92	0.61
10	LBG-904	0.62	0.30	0.92	0.55
11	LBG-1009	0.56	0.27	0.83	0.49
12	GBG-1	0.61	0.43	1.04	0.72
13	TBG-141	0.67	0.33	1.00	0.70
14	VBN-8	0.55	0.37	0.92	0.66
15	LBG-989	0.51	0.36	0.91	0.64
16	LBG-995	0.52	0.45	0.97	0.75
17	OBG-48	0.51	0.40	0.91	0.66
18	PU-31	0.53	0.45	0.98	0.77
19	LBG-1006	0.48	0.38	0.86	0.67
20	Tutiminumu	0.53	0.36	0.89	0.68
21	LBG-1010	0.53	0.38	0.91	0.69
22	LBG-932	0.49	0.33	0.81	0.55
23	PU-1822	0.51	0.40	0.91	0.66
24	TBG-104	0.55	0.40	0.95	0.73
25	LBG-645	0.51	0.38	0.89	0.68
26	LBG-999	0.52	0.34	0.86	0.60
27	LBG-996	0.54	0.37	0.91	0.69
28	TBG-125	0.45	0.25	0.70	0.55
29	PU-1801	0.57	0.29	0.86	0.64
30	LBG-1023	0.44	0.23	0.67	0.55
	Mean	**0.54**	**0.36**	**0.90**	**0.65**
	SEm	**0.03**	**0.02**	**0.03**	**0.03**
	CD	**0.07**	**0.05**	**0.10**	**0.08**
	CV(%)	**6.65**	**7.22**	**5.17**	**6.01**

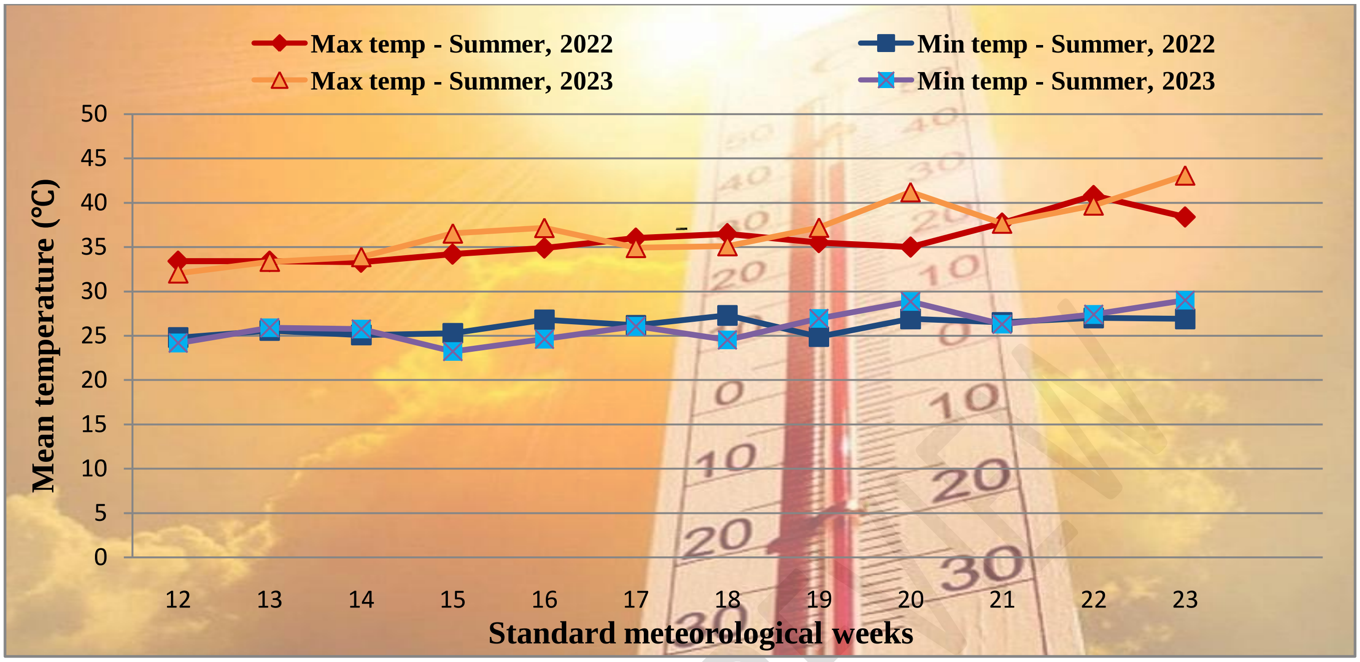

Fig. 1. Standard week wise mean temperatures during summer, 2022 and 23

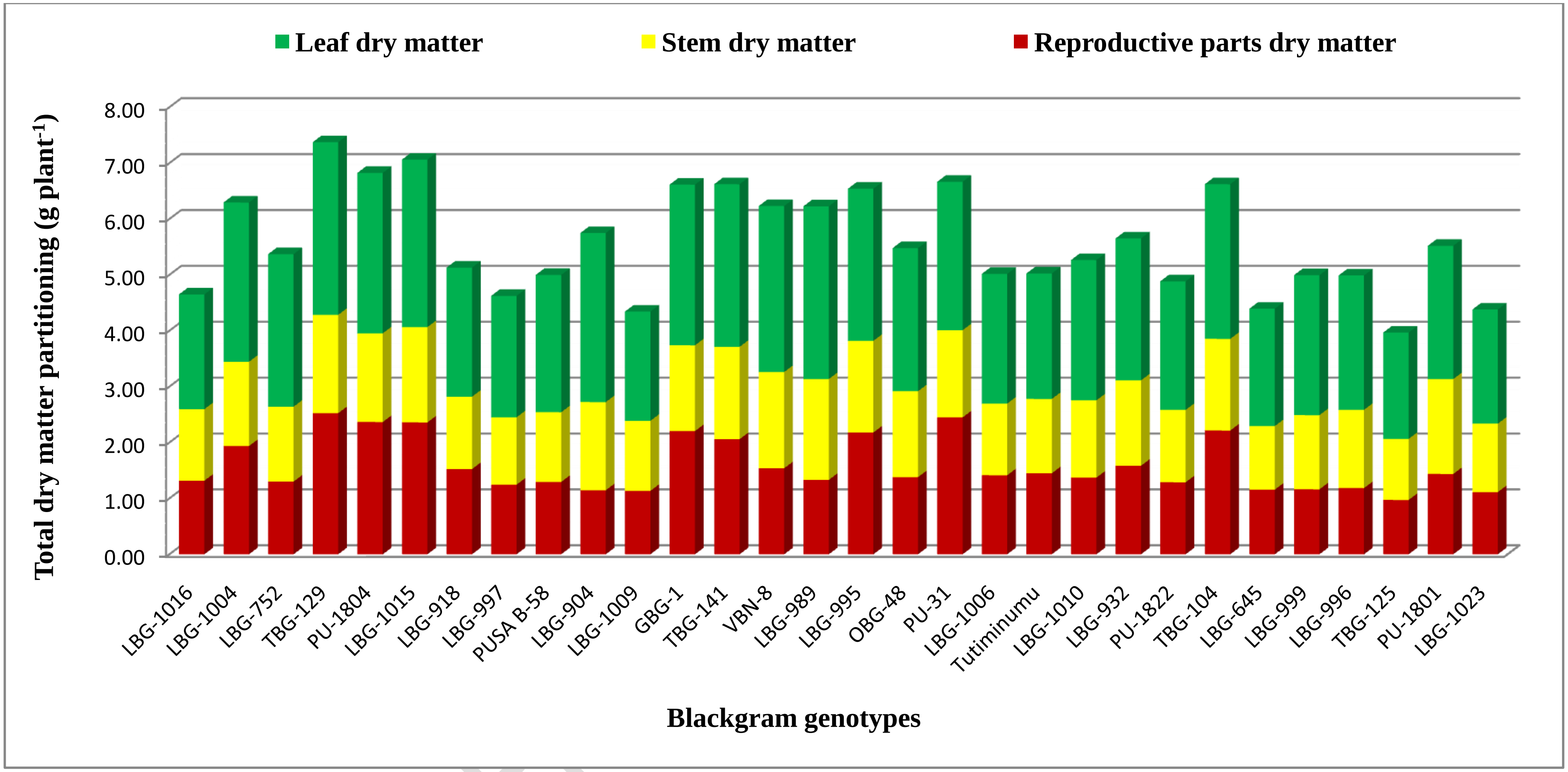

Fig. 2. Effect of high temperature stress on dry matter partitioning (g plant^{-1}) of blackgram genotypes at pod formation stage (pooled data)

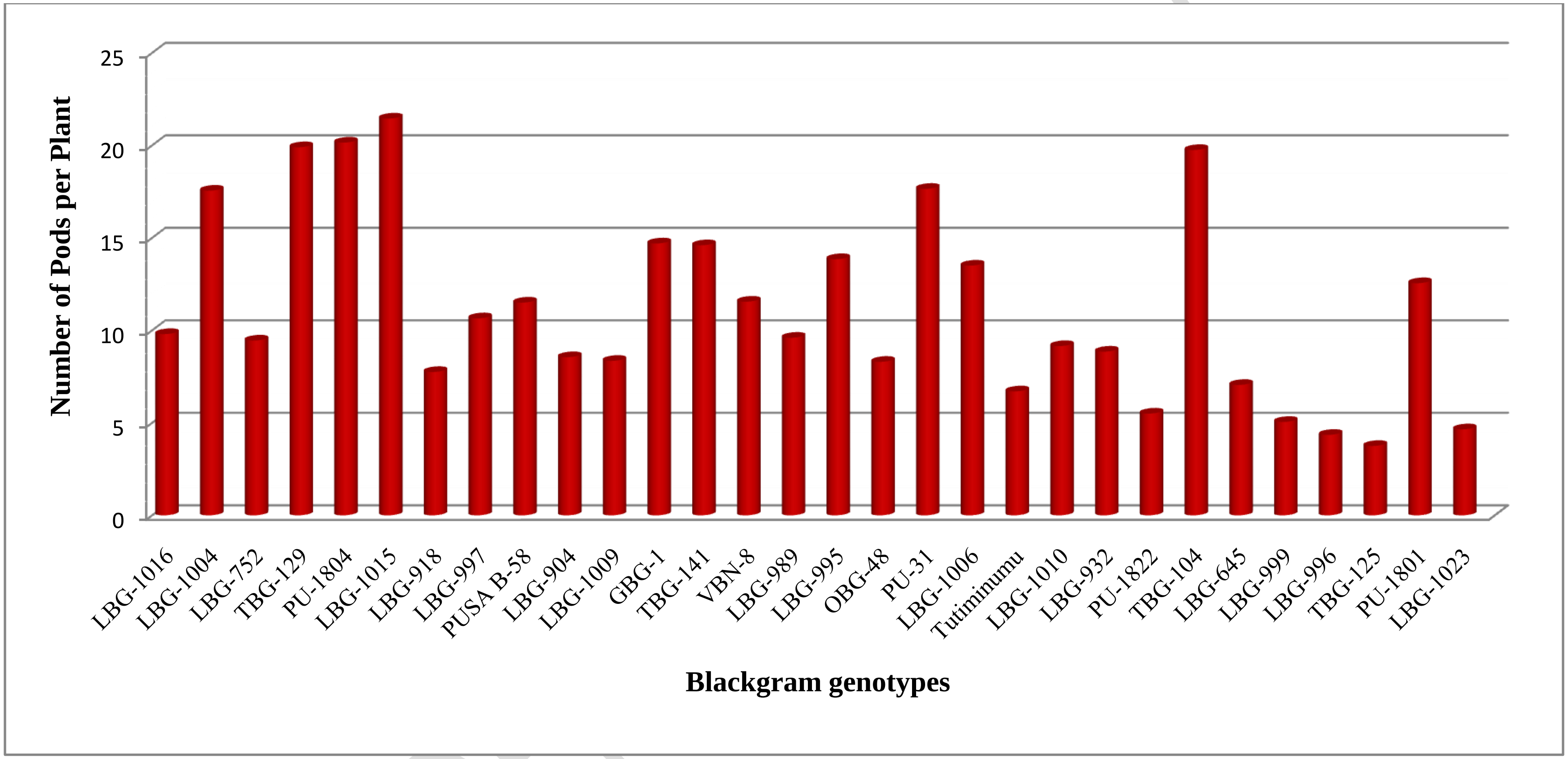

Fig. 3. Effect of high temperature stress on number of pods per plant of blackgram genotypes at pod formation stage (pooled data)

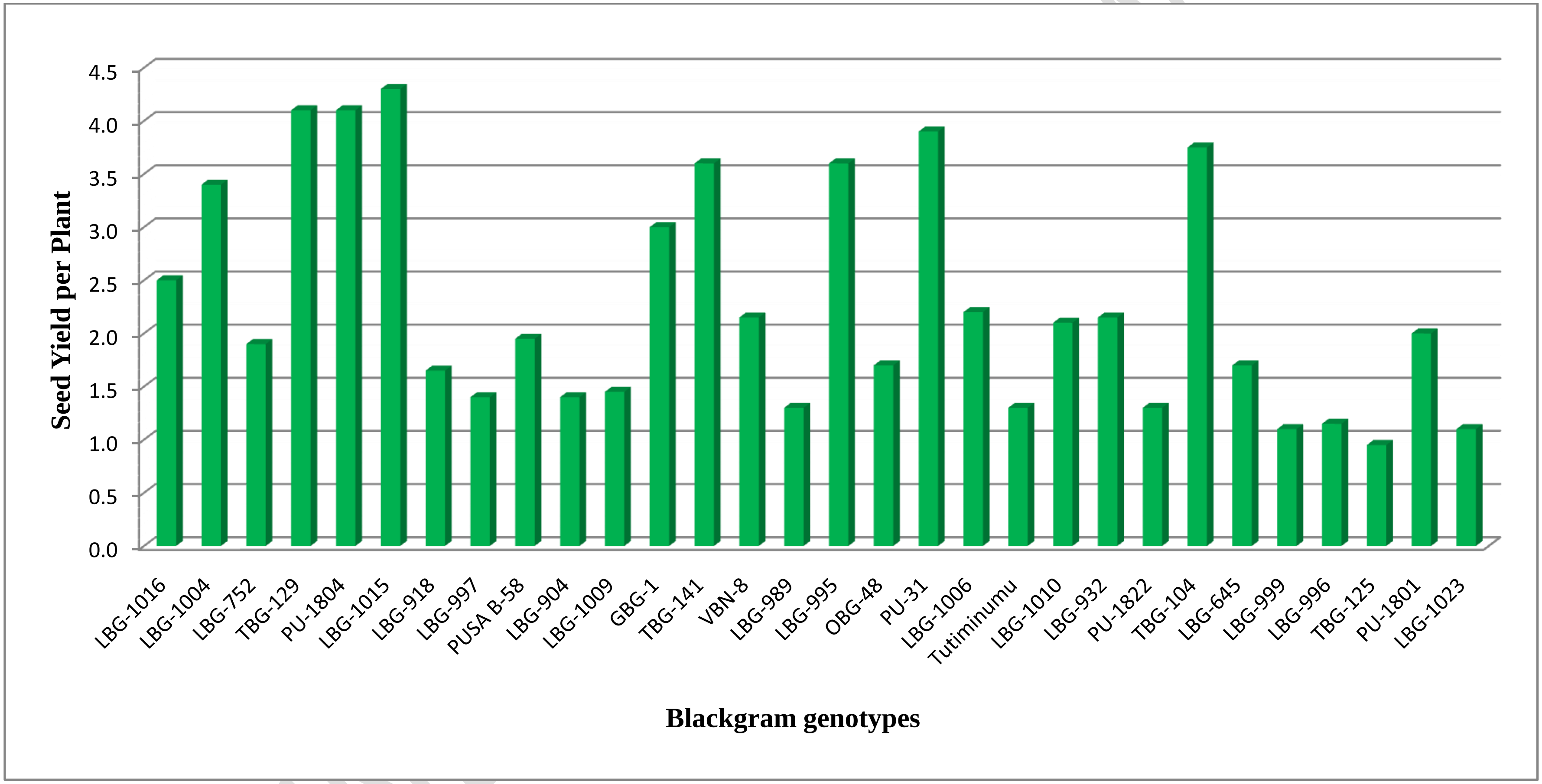

Fig. 4. Effect of high temperature stress on seed yield per plant (g plant^{-1}) of blackgram genotypes at pod formation stage (pooled data)