<u>Original Research Article</u>

INFLUENCE OF HIGH TEMPERATURE STRESS ON MORPHO-PHYSIOLOGICAL AND YIELD TRAITS OF BLACKGRAM (*Vigna mungo* L.) GENOTYPES

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 influence of high temperature stress on morpho-physiological and yield traits of blackgram genotypes. The experiment was carried out in randomized block design with 30 treatments and 2 replications. The study revealed that among the thirty blackgram genotypes screened for their tolerance to high temperature stress at flowering stage, the genotype, TBG-129, LBG-1015 and PU-1804 were found to withstand high temperature stress and maintain higher SPAD chlorophyll content, and higher seed yield per plant indicating tolerance to high temperature stress during both the years. These blackgram genotypes can be further used as donors in the pulse breeding program for development of heat resilent varieties.

Key words: Blackgram, High temperature stress, Flowering stage

Introduction

Blackgram is a short duration pulse crop grown in different ecologies and seasons across the country. In India, it is grown mainly in the rainy season (July-October), and in the southern part it is also cultivated as a winter season crop (November to February). However, its cultivation is not wide in the summer season due to excessive heat stress and lack of humidity in the atmosphere. Thus, availability of heat tolerant cultivars can bring more areas under blackgram cultivation. Previously, genetic variability for heat tolerance was reported in many food legumes (Sita *et al.*, 2017), but it is not yet explored in blackgram. It is a warm season food legume, which requires 25-35℃ temperature along with high humidity for its normal growth and development. However, prevailing high temperature (>35℃) during flowering results in thedeformation of flower parts or flower drop leading to negative impact on yield(Anitha*et al*., 2015)..

Transitory or constantly high temperature causes an array of morpho-anatomical, physiological and biochemical changes in plants, which affect plant growth and development and may lead to a drastic reduction in economic yield. Blackgram is typical day neutral plant it may flower within 30 days when temperature is around 30℃.Clearly, the research under high thermal regime shows that early phenology is the most important mechanism and pod set the primary yield component to be considered in heat tolerance breeding (Devasirvatham*et al*., 2015). The adverse effects of temperature stress can be mitigated by developing crop plants with improved thermotolerance using various genetic approaches. For this purpose, however, a thorough understanding of morpho-physiological responses of plants to high temperature, mechanisms of temperature tolerance and possible strategies for improving crop thermotolerance is imperative. Moreover, the current climate change scenario also leads to abrupt changes in mean temperature. Therefore, screening of blackgram genotypes for thermotolerance becomes more relevant under such situations.

Materials and methods

The experiment was carried out during summer, 2022 and 2023 at College Farm, Agricultural College, Bapatla, Acharya N.G Ranga Agricultural University.The experimental site is geographically located at 15°54’ N latitude and 80°47’ E longitude and at an altitude of 5.49 m above the 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 experiment was laid out to evaluate 30 blackgramgenotyopesin Randomized Block Design with two replications.Observations such as number of branches per plant, days to 50% flowering and maturity, number of nodules per plant, SPAD chlorophyll meter readings were recorded at 50% flowering during both years as it is more sensitive to high temperatures and yield parameters such as number of pods per plant (NPP), number of seeds per pod, test weight, pod weight, seed yield per plant (SYP) were recorded at harvest. The meteorological data for the growing season are shown in Figure 1.The mean maximum temperature was 35.5 and 37.2 ℃ at flowering during summer, 2022 and 23, respectively.

Comment [ARS1]: Do you consider other factors influencing crop performance, such as genetics (variety), Environment (Soil, pests, and diseases), and management practices?

No of branches plant^{-1}

The number of branches plant^{-1} was counted for five plants selected and tagged for non destructive measurement. The mean value was calculated and expressed as number of branches plant^{-1}.

Days to 50 % flowering

Visually flowering appears in 50 per cent plants in a plot, the date was noted and the days taken to flowering were calculated from the date of sowing and was expressed in number of days.

Days to 50 % maturity

When 50 per cent of the plants in a plot became brown/grey and dried, the date was noted and the days taken to maturity was calculated from the sowing date and was expressed in number of days.

SPAD Chlorophyll meter reading

SPAD (Soil Plant Analytical Development) Chlorophyll Meter Readings were recorded with Minolta chlorophyll meter (Model SPAD 502). In every tagged plant, total chlorophyll content was measured with SPAD and the readings were recorded on 3rd or 4th leaf from the top of each representative plant, between 10.00 AM to 12.00 Noon of the day by keeping on the different position of the leaf in the slot of the meter head and the average of these readings was considered as the value of one plant. The readings of five tagged plants per each plot were averaged and considered as SPAD chlorophyll meter reading of each plot.

Growing degree days (℃day)

A degree day or a heat unit is the departure from the mean daily temperature above the threshold temperature of the crop. Growing degree days (GDD) concept assumes that there is a direct and linear relationship between the growth of plants and temperatures.

For calculating growing degree days, weather data was collected at Meteorological Observatory of IMD located in Agricultural College Farm, Bapatla.

The temperature below which no growth takes place is the base temperature or threshold. It varies with the crop. In the current study, 10 ℃ is considered as the base temperature for blackgram. GDD was computed from the date of sowing to harvest of the crop to give accumulated GDD by using the following formula (Iwata, 1984) and expressed as ℃day.

$$\text{GDD} = \Sigma\frac{\text{Tmax}-\text{Tmin}}{2} \times T_b$$

Where,

Tmax = Maximum temperature

Tmin = Minimum temperature

T_b = Base temperature of the crop

Yield and yield attributes

Yield parameters such as number of pods per plant, number of seeds per pod, test weight, pod weight and seed yield per plant 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, (1985) 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

Comment [ARS2]: The discussion is inadequate, with insufficient citations in the results and discussion sections.

Number of branches per plant

The data pertaining to number of branches per plant ofblackgram genotypes grown under high temperature stress conditions during summer, 2022 and 23 were presented in the Table 1.Significant genotypic variability was observed among the genotypes with respect to number of branches per plantat flowering during summer, 2022 and 23. Number of branches per plant at flowering ranged from 3.5 to 3.7 during summer, 2022 and 23, respectively. During summer, 2022 maximum number of branches per plant was recorded in LBG-904 (4.0) which was at par with LBG-932 (4.0), LBG-1004 (3.8), TBG-129 (3.8), GBG-1 (3.8), TBG-141 (3.8), LBG-989 (3.8), PU-31 (3.8), LBG-752 (3.7), VBN-8 (3.7), LBG-1010 (3.7) and LBG-999 (3.7) whereas, minimum in LBG-645 (2.8), PU-1822 (2.9), PU-1801 (2.9), LBG-918 (3.0), TBG-125 (3.0), LBG-1016 (3.2), OBG-48 (3.2) and Tutiminumu (3.2). The genotype GBG-1 (4.3) recorded maximum number of branches per plant which was at par with LBG-1004 (4.0), LBG-904 (4.0), LBG-932 (4.0), TBG-129 (3.9), PU-1804 (3.9), VBN-8 (3.9) and LBG-1010 (3.9) whereas, minimum in LBG-645 (3.0) followed by LBG-918 (3.1), OBG-48 (3.1) and TBG-125 (3.3) during summer, 2023.Inspite of possessing higher branches per plant, the genotypes suchas LBG-904, LBG-932 and VBN-8 didn’t record higher yield under high temperature stress conditions during both the years.

Comment [ARS3]: Can you justify how temperature, rather than other factors, entirely influences this result?

Days to 50 % flowering and maturity

Significant genotypic variability was observed among the genotypes with respect to days to 50 % flowering, but days to maturity was found to be non significant during summer, 2022. There was no significant difference with respect to days to 50 % flowering and days to maturity during summer, 2023. During 2023, the crop received 50mm rainfall at 35 DAS due to which flowering was delayed. Plants avoid elevated temperature through early flowering and early maturity and these are considered as a part of temperature tolerance (Anitha*et al.* 2015). Under high temperature stress,during summer, 2022days to 50% flowering ranged from 32.5 to 41.0 days. In which LBG-1004 took less number of days to 50 % flowering followed by PU-31 (33.5) and LBG-1006 (33.5) whereas, in TBG 125, 50 % flowering happened in 41.0 days. The genotype LBG-1004 (32.5 days) was found to mature earlier than the other genotypes (63.5 days), whereas the genotypes TBG125, LBG-1023 and LBG-999 were late maturing. Days to 50 % flowering and days to maturity were low for the genotype LBG-1004 followed by PU-31 and LBG-1006.

With rising temperature phenological stages are progressed rapidly due to the availability of greater thermal units for less period of time, resulting in forced maturation (Taneja and Bishnol, 1990). Under high temperature conditions, early flowering and forced maturity were observed (Upadhaya*et al.*, 2011). Results showed that high temperature increased the rate of phenological development and thus shortened the grain filling time, resulting in reduction in yield, and the tolerant genotypes completed their life cycle with substantial earlier phenology compared to the susceptible ones. Similar results have been reported by Singh *et al.* (2005) in chickpea, who stated that the tolerant advanced breeding line DG 36 showed shorter phenophases with highest yield compared to susceptible genotypes. Our results also concur with the published reports of Devasirvatham*et al.*(2015) and Kiran *et al.*(2016) in chickpea, Baker *et al.* (1989) in soybean and Malaviarachchi*et al.*(2016) in greengram.

Number of nodules per plant

Number of nodules per plant varied significantly among the genotypes with mean values of 16.5 and 12.1 at flowering during summer, 2022 and 23, respectively (Table 1). At flowering, during summer, 2022 higher number of nodules per plant were recorded in PU-1804 (19.8) which was at par with TBG-129 (19.3), LBG-1004 (19.3), LBG-1016 (19.2), LBG-1015 (18.3), GBG-1 (18.2) and PU-31 (18.2) while, lower number of nodules per plant were recorded in LBG-1023 (13.8) followed by PU-1822 (14.0), TBG-125 (14.2), LBG-1010 (14.2), LBG-645 (14.3), Tutiminumu (14.3), LBG-996 (14.8), LBG-999 (15.0), PU-1801 (15.0), LBG-932 (15.3), LBG-995 (15.3) and LBG-989 (15.5). During summer, 2023 the genotype TBG-129 (14.7) recorded higher number of nodules per plant which was at par with PU-1804 (13.5) whereas, it was lower in LBG-1010 (10.5) followed by PUSA B-58 (10.8), TBG-125 (11.2), LBG-752 (11.3), LBG-997 (11.3), LBG-904 (11.3), LBG-1009 (11.3), LBG-989 (11.3), LBG-932 (11.5), LBG-1023 (11.7), LBG-918 (11.7) and OBG-48 (11.7).High temperature reduces the nodule formation, impairs nodule function and affects nodule structure (Roughley and Dart 1970, andKurdali 1996).Slightly increased day temperature (32.5 ºC) delayed nodulation, decreased total plant nitrogen fixation and longevity of the symbiotically active nodule population (Rawsthorne*et al.* 1985).

SPAD chlorophyll meter readings

Significant genotypic variability was observed among the genotypes with respect to SPAD chlorophyll meter readings at flowering during summer, 2022 and 23 (Table 1). Mean SPAD values at flowering ranged from 41.5 to 40.0 during summer, 2022 and 23, respectively. During summer, 2022 higher SPAD values were recorded in TBG-129 (47.6) followed by LBG-1015 (46.9), PU-1804 (45.5), TBG-104 (44.5), LBG-1004 (44.3), TBG-141 (43.1), PU-31 (42.9) and LBG-995 (42.2) while, it was lower in TBG-125 (35.6) which was at par with LBG-1023 (38.9), LBG-996 (39.1), LBG-645 (39.5), Tutiminumu (39.6) and LBG-989 (40.0). During summer, 2023 the genotype TBG-129 (45.1) recorded higher SPAD values which was at par with PU-1804 (42.6), TBG-141 (42.3), PU-31 (42.1), LBG-1006 (42.1), TBG-104 (41.9), LBG-1015 (41.4) and GBG-1 (41.4) whereas, lower values were recorded in TBG-125 (35.5) followed by LBG-1023 (36.8), LBG-645 (38.3), LBG-999 (38.3), LBG-989 (38.4), LBG-1010 (38.7), PUSA B-58 (38.9) and LBG-996 (38.9). Higher SCMR indicates more nitrogen and chlorophyll and can therefore be considered as an index for genotypes evaluation (Anitha*et al.*,2015). Leaf chlorophyll that helps in photosynthesis reduced under high thermal stress (Sharma *et al.*, 2016).The poor SCMR value for the sensitive genotypes is primarily due to failure of chlorophyll synthesis at high temperatures. Our results concur with the published reports of Haritha (2020) who reported lower SCMR values in susceptible genotypes.

Growing Degree Days (GDD) (℃day)

The accumulated growing degree days (GDD) were recorded at 20, 40, 60 DAS and at harvest under high temperature stress. Total accumulated GDD from sowing to harvest ranged from 1481.7 and 1610.7 ℃ day during summer, 2022 and 23, respectively. Accumulation of higher GDD was observed during summer, 2023 due to duration of the crop, as the crop received 40 mm rainfall at the onset of flowering due to which flowering was delayed and took more time to mature than the summer, 2022.

Yield and yield attributes

Number of pods per plant

Temperature stress at flowering affects the seed yield by decreasing the pod number per plant which is the main yield contributing trait.Number of pods per plant varied significantly among the blackgram genotypes grown under high temperature stress during 2022 and 23 (Table 2). It decreased from 12.5 to 9.9 with increase in temperature from first year to second year. The total NPP was higher in LBG-1015 (25.8) followed by TBG-104 (25.3), PU-1804 (23.3), LBG-129 (22.0) and LBG-1004 (22.0), whereas it was lower in TBG-125 (4.0) followed by LBG-996 (4.6), LBG-1023 (4.8), and LBG-999 (5.3) during summer, 2022. The genotype TBG-129 (17.3) recorded higher number of pods per plant which was at par with LBG-1015 (17.1) and PU-1804 (17.0) whereas, lower number of pods per plant was recorded in TBG-125 (3.5) followed by LBG-996 (4.1) and LBG-1023 (4.8) during summer, 2023. The thermotolerant genotypes, TBG-129, LBG-1015 and PU-1804 recorded higher number of pods per plant during both the years of study which might be due to higher chlorophyll retention, CSI, CTD, lesser electrolyte leakage and higher antioxidant enzyme activity. 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. 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.

Number of seeds per pod

Significant genotypic variability was observed among the genotypes with respect to number of seeds per pod during summer, 2022 and 23 (Table 2). Mean number of seeds per pod ranged from 4.2 to 3.7 during summer, 2022 and 2023, respectively. It was higher in LBG-1015 (5.5) followed by PU-1804 (5.4) and TBG-129 (5.2) while, it was lower in LBG-996 (3.4), LBG-1009 (3.4) which was at par with VBN-8, LBG-904, Tutiminumu (3.5), LBG-932 (3.6), TBG-125(3.6), LBG-645 (3.6), LBG-918 (3.8), PUSA B-58 (3.8), LBG-989 (3.8), PU-1822 (3.9) and LBG-1023 (3.9) during summer, 2022. The genotype PU-1804 (3.6) recorded maximum number of seeds per pod which was at par with PU-31(3.6) whereas, TBG-125 (1.5) recorded minimum number of seeds per pod during summer, 2023. Results showed that TBG-125 recorded lesser number of seeds per pod which might be due to sensitivity of pollen to high temperatures which in turn affects seed setting and pollination. The loss of viability of pollen or stigma under heat stress conditions may be the major reason for the reduction in the number of seeds produced in legumes (Wang *et al.,* 2006). Our results concur with the published reports of Haritha (2020) who reported lower seed set in blackgram genotype TBG-125.

Test weight (g plant^{-1})

There was no significant difference among the genotypes with respect to test weight during summer, 2022 whereas, it was found to be significant during summer, 2023 (Table 2). Higher test weight was recorded in PU-1804 (3.8 g plant^{-1}) which was at par with LBG-1004 (3.7 g plant^{-1}), TBG-129 (3.7 g plant^{-1}), LBG-1015 (3.7 g plant^{-1}), PU-1801 (3.7 g plant^{-1}), LBG-1010 (3.6 g plant^{-1}), GBG-1 (3.5 g plant^{-1}), TBG-141 (3.5 g plant^{-1}), LBG-932 (3.5 g plant^{-1}), TBG-104 (3.5 g plant^{-1}) and LBG-645 (3.5 g plant^{-1}) whereas, lower was recorded in TBG-125 (2.9 g plant^{-1}) followed by LBG-1023 (3.0 g plant^{-1}), LBG-752 (3.1 g plant^{-1}), LBG-918 (3.1 g plant^{-1}), LBG-989 (3.1 g plant^{-1}), LBG-995 (3.1 g plant^{-1}), Tutiminumu (3.1 g plant^{-1}), LBG-1016 (3.2 g plant^{-1}) and LBG-997 (3.2 g plant^{-1}) during summer, 2023. The reduction in test weight in susceptible genotypes was due to the occurrence of high temperatures from flowering to maturity, which resulted in reduced grain filling time, resulting in lower yield (Neeraj *et al.,* 2012).

Pod weight(g plant^{-1})

Significant genotypic variability was observed among the genotypes with respect to pod weight during summer, 2022 and 23 (Table 2). Mean pod weight ranged from 4.1to3.2g plant^{-1}during summer, 2022 and 23, respectively. Higher pod weight was recorded in TBG-129 (6.7 g plant^{-1}) which was at par with TBG-104 (6.7 g plant^{-1}), PU-1804 (6.5 g plant^{-1}), LBG-1015 (6.5 g plant^{-1}) and PU-31 (6.3 g plant^{-1}) while, it was lower in LBG-996 (1.5 g plant^{-1}) followed by LBG-1023 (1.8 g plant^{-1}), TBG-125 (1.9 g plant^{-1}) and LBG-999 (1.9 g plant^{-1}) during summer, 2022. During summer, 2023 higher pod weight was recorded in TBG-129 (5.2 g plant^{-1}) which was at par with LBG-1015 (5.0 g plant^{-1}), PU-1804 (4.8 g plant^{-1}), PU-31 (4.8 g plant^{-1}) and TBG-104 (4.7 g plant^{-1}) whereas, it was lower in LBG-1023 (1.9 g plant^{-1}) followed by LBG-999 (1.9 g plant^{-1}), TBG-125 (2.0 g plant^{-1}), PU-1822 (2.1 g plant^{-1}), LBG-997 (2.2 g plant^{-1}), OBG-48 (2.2 g plant^{-1}) and LBG-996 (2.2 g plant^{-1}).The genotypes TBG-129, PU-1804, LBG-1015, PU-31 and TBG-104 recorded higher pod weight indicating their tolerance to high temperatures. Whereas, lower pod weight was recorded in LBG-1023, LBG-996, TBG-125 and LBG-999 during both the years. Similar results of higher pod weight in thermotolerant blackgram genotypes were previously reported by Anitha*et al*. (2015).

Seed yield per plant (g plant^{-1})

Significant genotypic variability was observed among the genotypes with respect to seed yield per plant during summer, 2022 and 23 (Table 2). Mean seed yield per plant ranged from 2.5 and 2.0 g plant^{-1} during summer, 2022 and 2023, respectively. Seed yield per plant was higher in LBG-1015 (5.4 g plant^{-1}) followed by PU-1804 (5.2 g plant^{-1}) and TBG-129 (5.0 g plant^{-1}) whereas, TBG-125 (0.8 g plant^{-1}) recorded lower seed yield per plant which was at par with LBG-1023 (0.9 g plant^{-1}), LBG-999 (0.9 g plant^{-1}), LBG-996(1.1 g plant^{-1}), PU-1822(1.1 g plant^{-1}), LBG-989(1.1 g plant^{-1}) and LBG-997 (1.1 g plant^{-1}) during summer, 2022. Higher seed yield per plant was recorded in TBG-129(3.2 g plant^{-1}) and LBG-1015 (3.2 g plant^{-1}) followed by PU-1804 (3.0 g plant^{-1}) while, lower seed yield per plant was recorded in TBG-125 (1.1 g plant^{-1}) which was at par with LBG-1023(1.3 g plant^{-1}), LBG-999 (1.3 g plant^{-1}) and LBG-996 (1.3 g plant^{-1}) during summer, 2023. In the current study, the genotypes LBG-1015, TBG-129 and PU-1804 recorded higher seed yield per plant during both the years. Whereas, lower seed yield was recorded in TBG-125, LBG-1023, LBG-999 and LBG-996 indicating their sensitivity to high temperatures. 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 seed yields.The prevailing high temperatures during summer, 2023 caused drastic reduction in seed yield which might be due to destruction of chlorophyll that in turn decreased the translocation of photosynthates from source to sink. 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 morpho-physiological and yield traits was assessed over 2 years in 30 blackgram genotypes grown under heat stress conditions during flowering stage.The crop experienced very high temperatures during 2023 at flowering compared to summer, 2022 which affected the growth and yield drastically.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 tolerant genotypes identified in the present study can be further evaluated 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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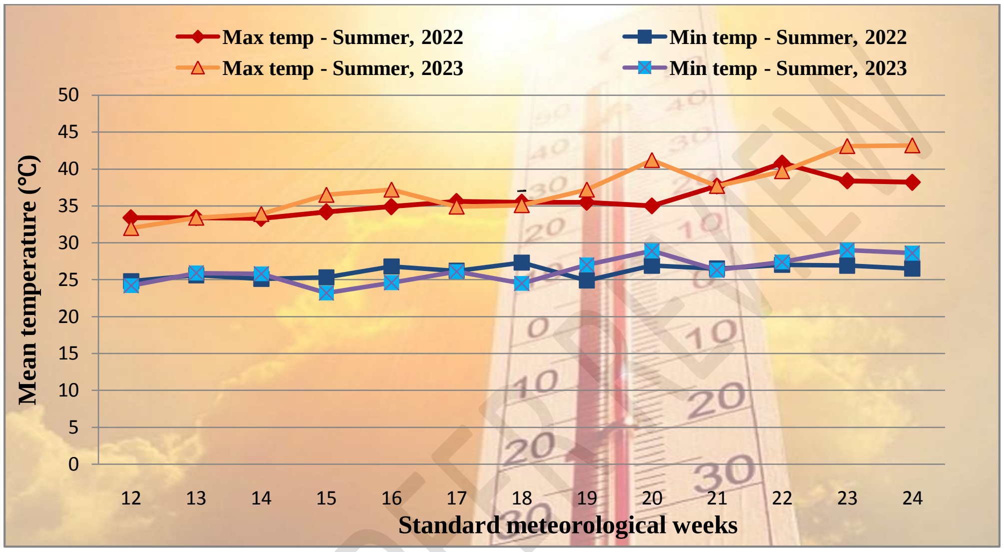

Fig.1 Standard week wise meterological data during crop growth period of blackgram genotypes during summer, 2022 and 23.

Table1. Effect of high temperature stress on morpho-physiological traits of blackgram genotypes

S.No	Genotypes	Morpho-Physiological traits					
		Number of branches per plant		Number of nodules per plant		SPAD Chlorophyll meter readings	
		Summer, 2022	Summer, 2023	Summer, 2022	Summer, 2023	Summer, 2022	Summer, 2023
1	LBG-1016	3.2	3.6	19.2	12.2	40.5	39.4
2	LBG-1004	3.8	4.0	19.3	12.7	44.3	40.1
3	LBG-752	3.7	3.8	17.2	11.3	40.1	39.9
4	TBG-129	3.8	3.9	19.3	14.7	47.6	45.1
5	PU-1804	3.5	3.8	19.8	13.5	45.5	42.6
6	LBG-1015	3.5	3.8	18.3	12.8	46.9	41.4
7	LBG-918	3.0	3.1	17.8	11.7	40.2	39.0
8	LBG-997	3.3	3.7	16.5	11.3	41.1	39.2
9	PUSA B-58	3.4	3.7	16.3	10.8	40.8	38.9
10	LBG-904	4.0	3.9	17.0	11.3	41.3	39.4
11	LBG-1009	3.4	3.7	16.2	11.3	40.6	40.9
12	GBG-1	3.8	4.3	18.2	12.7	42.0	41.4
13	TBG-141	3.8	3.8	18.0	12.8	43.1	42.3
14	VBN-8	3.7	3.9	16.8	12.5	40.6	39.2
15	LBG-989	3.8	3.7	15.5	11.3	40.0	38.4
16	LBG-995	3.5	3.8	15.3	12.8	42.2	40.4
17	OBG-48	3.2	3.1	16.2	11.7	40.8	39.3
18	PU-31	3.8	3.8	18.2	13.3	42.9	42.4
19	LBG-1006	3.3	3.7	16.7	12.3	40.7	42.4
20	Tutiminumu	3.2	3.6	14.3	12.5	39.6	39.9
21	LBG-1010	3.7	3.9	14.2	10.5	41.1	38.7
22	LBG-932	4.0	4.0	15.3	11.5	40.8	39.2

23	PU-1822	2.9	3.7	14.0	12.3	41.4	40.0
24	TBG-104	3.5	3.7	17.3	13.2	44.5	41.9
25	LBG-645	2.8	3.0	14.3	12.7	39.5	38.3
26	LBG-999	3.7	3.7	15.0	12.8	41.3	41.0
27	LBG-996	3.3	3.7	14.8	11.3	39.1	38.9
28	TBG-125	3.0	3.3	14.2	11.2	35.6	35.5
29	PU-1801	2.9	3.6	15.0	12.5	40.6	39.7
30	LBG-1023	3.3	3.6	13.8	11.7	38.9	36.8
	Mean	**3.5**	**3.70**	**16.5**	**12.2**	**41.5**	**40.0**
	SEm±	**0.1**	**0.1**	**0.6**	**0.5**	**1.6**	**1.4**
	CD(0.05)	**0.4**	**0.4**	**1.7**	**1.3**	**4.4**	**4.0**
	CV%	**5.6**	**5.1**	**5.3**	**5.4**	**5.3**	**5.0**

Table 2. Effect of high temperature stress on yield and yield attributes of balckgram genotypes

S.No	Genotypes	Yield and yield attributes									
		Number of pods per plant		Number of seeds per plant		Test weight (g plant^{-1})		Pod weight (g plant^{-1})		Seed yield per plant (g plant^{-1})	
		Summer, 2022	Summer, 2023	Summer, 2022	Summer, 2023	Summer, 2022	Summer, 2023	Summer, 2022	Summer, 2023	Summer, 2022	Summer, 2023
1	LBG-1016	10.8	8.8	4.0	2.7	4.0	3.2	4.7	3.7	2.9	2.1
2	LBG-1004	22.0	13.1	4.8	3.0	4.1	3.7	6.2	4.3	4.0	2.8
3	LBG-752	9.8	9.1	4.4	2.2	4.0	3.1	3.9	2.5	2.2	1.6
4	TBG-129	22.5	17.3	5.2	3.2	4.3	3.7	6.7	5.2	5.0	3.2
5	PU-1804	23.3	17.0	5.4	3.6	4.1	3.8	6.5	4.8	5.2	3.0
6	LBG-1015	25.8	17.1	5.5	3.1	4.2	3.7	6.5	5.0	5.4	3.2
7	LBG-918	8.0	7.5	3.8	2.3	3.9	3.1	3.6	2.8	1.7	1.6
8	LBG-997	9.5	11.8	4.2	2.3	4.0	3.2	2.6	2.2	1.1	1.7
9	PUSA B-58	14.1	8.9	3.8	2.3	4.0	3.3	4.5	3.3	2.3	1.9
10	LBG-904	9.3	7.8	3.5	2.2	3.9	3.3	2.7	3.2	1.2	1.6
11	LBG-1009	9.0	7.7	3.4	2.4	3.9	3.4	2.7	2.7	1.2	1.7
12	GBG-1	15.0	14.4	4.9	3.4	4.1	3.5	6.1	4.1	3.4	2.6
13	TBG-141	15.5	13.7	4.3	3.1	4.1	3.5	6.1	4.1	4.4	2.8
14	VBN-8	12.8	10.3	3.5	3.1	4.0	3.4	4.0	3.6	2.2	2.1
15	LBG-989	9.2	10.0	3.8	2.8	4.0	3.1	2.4	2.7	1.1	1.5
16	LBG-995	15.5	12.2	4.1	3.0	4.1	3.1	6.1	3.1	4.3	2.9
17	OBG-48	9.3	7.3	4.3	2.9	3.9	3.2	3.3	2.2	1.7	1.7
18	PU-31	19.5	15.8	4.7	3.6	4.1	3.3	6.3	4.8	4.7	3.1
19	LBG-1006	15.7	11.3	4.8	3.0	4.1	3.2	4.6	3.0	2.8	1.6
20	Tutiminumu	6.0	7.4	3.5	2.5	4.0	3.1	2.1	2.4	1.1	1.5

21	LBG-1010	12.8	5.5	4.6	2.6	4.2	3.6	4.6	3.4	2.5	1.7
22	LBG-932	10.5	7.2	3.6	2.4	4.0	3.5	3.7	2.7	2.1	2.2
23	PU-1822	5.5	5.5	3.9	2.7	3.9	3.4	2.8	2.1	1.1	1.5
24	TBG-104	25.3	14.2	4.8	3.0	4.2	3.5	6.7	4.7	4.7	2.8
25	LBG-645	7.2	6.9	3.6	2.6	4.0	3.5	3.7	2.6	1.8	1.6
26	LBG-999	5.3	4.8	4.1	2.4	3.8	3.4	1.9	1.9	0.9	1.3
27	LBG-996	4.6	4.1	3.4	2.7	3.9	3.2	1.5	2.2	1.0	1.3
28	TBG-125	4.0	3.5	3.6	1.5	3.8	2.9	1.9	2.0	0.8	1.1
29	PU-1801	13.3	11.8	4.4	3.1	4.0	3.7	4.0	3.0	2.3	1.7
30	LBG-1023	4.8	4.5	3.9	2.3	3.9	3.0	1.8	1.9	0.9	1.3
	Mean	**12.5**	**9.9**	**4.2**	**2.7**	**4.0**	**3.3**	**4.1**	**3.2**	**2.5**	**2.0**
	SEm±	**0.5**	**0.3**	**0.2**	**0.1**	**0.2**	**0.1**	**0.2**	**0.2**	**0.1**	**0.1**
	CD(0.05)	**1.3**	**1.0**	**0.5**	**0.3**	**NS**	**0.4**	**0.4**	**0.5**	**0.3**	**0.2**
	CV%	**5.2**	**5.0**	**5.5**	**5.5**	**6.7**	**5.6**	**5.3**	**7.0**	**5.2**	**5.5**