

RESEARCH ARTICLE

Physiological Changes and Yield Responses of Greengram (*Vigna radiata* L.)Under Elevated Temperature Stress

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ABSTRACT

	Pulses are one of the important food crops due to higher protein content.
	Among the pulses, greengram (Vigna radiataL.) is popular and major grain
	legume used for consumption since ancient days. Elevated temperature
	stress during critical crop growth stages affects yield in greengram and
	lead to very low productivity Worldwide. Hence, it is essential to study the
	responses of critical growth stages of greengram under elevated temperature
	stress. With this background, the present investigation was carried out in
	CO 8 variety of greengram to study the physiological characters and yield
Received : 10 th September, 2018	responses of greengram under different elevated temperature stress
Revised : 1 st February, 2019	conditions. The experiment was conducted in the open top chambers located
Accepted: 6 th February, 2019	in the Department of Crop Physiology, Tamil Nadu Agriculture University,
	Coimbatore during 2016-2017. Elevated temperature stress was given
	two levels, by raising the temperature up to 2° C and 4° C from the ambient
	temperature. Plants subjected to an elevated temperature at various
	stages viz., vegetative, flowering and pod development. Observations on
	various physiological parameters viz., leaf area, gas exchange parameters
	like photosynthetic rate, stomatal conductance, transpiration rate, leaf
	temperature were recorded. Also, osmotic potential and osmotic adjustments
	were studied under stress period. The response of yield was also recorded
	under different elevated temperature stress. Among the growth stages, the
	flowering stage was more critical to the elevated temperature and the impact
	of 4°C raise from ambient temperature was higher when compared with the
	elevated temperature of 2°C.

Keywords : Leaf area, gas exchange parameters, osmotic adjustment and yield traits.

INTRODUCTION

Pulses are a part of the daily diet of many vegetarians around the world. Pulses are rich in protein content. Pulse crops have a unique role to play in the global nitrogen cycle, as legumes and pulses fix atmospheric nitrogen in soils. Pulses are popularly known as Poor man's meat and rich man's vegetable. They contribute significantly to the nutritional security of the country. Among pulses, Greengram (Vigna radiataL.) is one of the most ancient and extensively grown pulse crops of India. The importance of greengram is linked to its high protein content and other essential minerals. Being a short duration crop, it also provides an excellent green fodder to the livestock animals. Like other legumes, mung bean fixes atmospheric nitrogen (58-109 kg/ha) in symbiosis with Rhizobium, by which the crop not only meet its own nitrogen demand but also improves the soil fertility (Ali and Gupta, 2012). It ranks second after chickpea in terms

of cultivated area in India (Rathod and Gawande, 2014). The productivity of greengram in India is very low and far below when compared to other greengram growing countries. Suitable climate for the cultivation of green gram should be warm humid and within a cardinal temperature range of 25°C to 35°C, with moderate rainfall. Conditions comprising high mean temperature and long day photoperiod may adversely affect the flowering time. Tamil Nadu has 0.19 million ha under greengram cultivation with production and productivity of 0.15 metric tonnes and 775 kg/ha respectively. Among the various yield-limiting factors, environmental stresses particularly water and temperature play a major role. Pulses are very sensitive to drought, water logging and high temperature. Climate change has already caused a fall in crop yield, and the expected further alteration will also increase the negative effect on crop productivity by exacerbating other related stress conditions such as water shortages (Bita and Gerats, 2013). Global temperatures have increased in the past 100 years by an average of 0.86°C (IPCC, 2013). Elevated temperature (above 40°C) caused significant flower shedding in mung bean (Khattak *et al.*, 2009). Growing food legume demand and global warming would further push the crop to heat stress environment. The predicted changes in temperature, their associated impacts on rainfall, consequent availability of water to crops and extreme weather events are likely to affect the potential production of pulses. With this background, the objectives were formulated for studying the physiological changes and yield responses of greengram (*VignaradiataL.*) under elevated temperature stress.

MATERIAL AND METHODS

The pot culture experiment was conducted during 2016-2017 in the open top chambers located in the Department of Crop Physiology (11°N latitude, 77°E longitude and 426.7 MSL), TNAU, Coimbatore to study the physiological changes and yield response ofgreengram under elevated temperature stress. The latest variety in greengram CO 8 was taken for the experiment. Seeds were obtained from Department of Pulses, Tamil Nadu Agricultural University (TNAU), Coimbatore. The seeds were treated with bavistin @ 2g kg¹of seeds for protection against seed-borne diseases. The seeds were sown uniformly in the pots. The recommended dose of fertilizers and a common package of practices were followed in a timely fashion. The treatments are the ambient temperature that exists under open field condition (T₁), Elevated temperature of 2°C from the ambient temperature (T₂), Elevated temperature of 4°C from the ambient temperature (T_3) . The treatments were imposed during Vegetative (S_1) , Flowering (S_2) and Pod development stages (S_3) . The physiological parameters and yield traits were recorded under elevated temperature stress. The experiment was laid out in Factorial Completely Randomized Design (FCRD) with four replications.

Leaf area per plant was measured using a Leaf area meter (LICOR, Model LI 3000) and expressed as cm² plant⁻¹. Gas exchange parameters were measured from non-detached young and fully expanded leaves using a portable photosynthetic system (PPS) (ADC Bio-Scientific Ltd.). Using PPS, the following gas exchange parameters were recorded and the units expressed as in parentheses. Photosynthetic rate (Pn: µmol CO₂ m⁻² s⁻¹), Transpiration rate (E: mmol H₂O m⁻² s⁻¹), Stomatal conductance (g.: mol H₂O m⁻² s⁻¹), Leaf temperature (T: °C). The osmotic potential was determined using a vapour pressure osmometer (Vapro Model 5520 Wescor Inc., Logan, UT, USA). The following conversion equation was used to compute the osmotic potential (in Mpa)

[(Osmolality mmol kg-1) x (0.0832) x (310)] / 10000

The osmotic adjustment was calculated as the difference between the turgid potential in the control and stress treatment (Babu *et al.* 1999).

Total pod weight was determined by collecting the number of pods produced in each plant. The pods were taken from four randomly selected plants in each replication under each treatment at the harvest stage. The total pod weight was expressed in gram per plant. For seed yield, the number of seeds produced in each plant was collected randomly from four plants in each replication from each treatment at the harvest stage. The seed yield was expressed in gram per plant.

The data arrived and collected on various parameters from the pot culture experiment were analyzed statistically in FCRD (Factorial Completely Randomized Design) as per the procedure suggested by Gomez and Gomez (1984). Wherever the treatment differences were found significant, critical differences were worked out at five per cent probability level and the values were presented in the relevant tables.

RESULTS AND DISCUSSION

Decreased leaf area was observed across all the stages *viz.*, vegetative stage (S_1) , flowering stage (S_1) and pod development stage (S_3) under elevated temperature stress. Higher leaf area was observed in all the stages of T_1 (97.29 at S_1 ,134.56at S_2 , 148.91 at S_3) when compared with T_2 (86.67 at S_1 , 121.40 at S_2 , 132.51 at S_3) and T_3 (74.93 at S_1 , 104.66 at S_2 , 116.15 at S_3). A significant difference was observed between the treatments. Among the treatments, T_3 recorded minimum leaf area in all the stages. The data were displayed in Table 1. **Table.1. Effect of elevated temperature on leaf area (cm²pant⁻¹) in greengram**

Treatments	Crop	Maan		
	S ₁	\$ ₂	S ₃	Mean
T ₁	97.29	134.56	148.91	126.91
T ₂	86.67	121.40	132.51	113.52
T ₃	74.93	104.66	116.15	98.57
Mean	86.29	120.20	132.52	113.00
		Т	S	ΤS
SED		2.70	2.70	4.69
	CD (P 0 05)	5 55**	5 55**	9 62 ^(NS)

**, NS denote significance level at P<0.01 and non-significant respectively T,: Ambient temperature that exists S,: Vegetative stage

under open field condition

T_: Elevated temperature of 2°C from S_: Flowering stage

the ambient temperature

 $T_{\rm s} {\rm :}$ Elevated temperature of 4°C from $~S_{\rm s} {\rm :}$ Pod development stage the ambient temperature

Extension of the cell wall is decreased by stress and high pH which results in structural changes in the plant cell wall, finally reducing the rate of growth of the stressed plants compared to unstressed plants (Burssenset *al.*, 2000; Pakornet *al.*, 2009).

The data on photosynthetic rate showed a significant difference between treatments and stages. The photosynthetic rate was recorded at vegetative (S_1) and flowering stages (S_2).

Treatments —	Crop §	Maan		
	S ₁	S ₂	S ₃	Mean
T ₁		· · · · · · · · · · · · · · · · · · ·		4.24
T ₂	3.82	2.83	3.24	3.29
T ₃	3.27	2.11	2.31	2.56
Mean	3.77	3.05	3.26	3.36
		Т	S	ΤS
	SED	0.18	0.18	0.32
	CD (P 0.05)	0.38**	0.38*	0.66 ^(NS)

Table 2.	Effect of	elevated	temperature	on total	nod weight	(g plant ^{_1})	in greengram
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*, ** and NS denote significance level at P<0.05, P<0.01 and non-significant respectively

Among the treatments, plants are grown in ambient condition (T₁) recorded the more photosynthetic rate at S₁(16.8) and at S₂(23.5) when compared to elevated temperature condition (T₂ and T₃)(Fig. 1). The photosynthetic rate was reduced under elevated temperature i.e. in T₂ (13.5 at S₁, 21.8 at S₂) and in T₃ (11.3 at S₁, 17.0 at S₂). The

results of the present study is similar to the findings of Djanaguiramanet *al.* (2011) who found that hightemperature stress during flowering in soybean plants decreased the photosynthetic rate by 20.5 per cent compared with those grown at ambient temperature. Transpiration rate was also recorded at vegetative (S_1) and flowering stage (S_2).

Table.3. Effect of elevated t	emperature on seed	yield (g plant ⁻¹)	in greengram
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Treatments —	Crop §	Maan		
	S ₁	S ₂	S ₃	Mean
T ₁				3.67
T ₂	3.50	3.00	2.89	3.11
T ₃	3.11	2.02	2.47	2.53
Mean	3.41	2.89	3.00	3.10
		Т	S	ΤS
	SED	0.12	0.12	0.20
	CD (P 0.05)	0.24**	0.24*	0.42 ^(NS)

*, ** and NS denote significance level at P<0.05, P<0.01 and non-significant respectively

The data indicated a significant difference between treatments under elevated temperature(Fig 2). Higher transpiration rate was observed in elevated temperature stress than ambient condition. i.e. in $T_2(10.80 \text{ at } S_1, 14.50 \text{ at } S_2)$ and T_3



Fig.1. Effect of elevated temperature on photosynthetic rate in greengram

(13.70 at S_1 , 16. 30 at S_2). Decreased leaf number and biomass due to high temperature may lead to a reduced surface area for reactions, such as photosynthesis and increased transpiration rate. It was evident that the rate of transpiration is higher when there is a rise in the atmospheric temperature (Weerakoonet *al.*, 2008).



Fig.2.Effect of elevated temperature on transpiration rate in greengram

Stomatal conductance was an important parameter for deciding the photosynthetic rate which was represented in Fig 3. In T_2 and T_3 , stomatal conductance was significantly reduced when compared to the control condition (T_1). The lowest value was observed in T_3 at both stages (0.53 at S_1 , 0.75 at S_2). Similar results were obtained by Djanaguiramanet *al.* (2011) who found that the stomatal conductance was declined by 12.5 per cent under high-temperature stress during flowering in soybean.

The Osmotic potential (OP) of leaves was

measured in terms of 'Mega Pascal'.Osmotic adjustment (OA) was also observed in the leaves of control (T_1) and stressed $(T_2 \text{ and } T_3)$ plants. Osmotic potential and osmotic adjustment have an inverse relationship under stress conditions which is presented in Fig 4. The osmotic adjustment can be observed from the results of osmotic potential. It was assessed from the difference between plants grown in ambient temperature (T_1) and elevated temperature (T_2 and T_3). Osmotic adjustment was recorded highest in T_3 (0.50 at S_1 , 0.43 at S_2) than in T₂ (0.22 atS₁, 0.23 atS₂). Decline in osmotic potential during high temperature can be a result of either simple passive concentration of solutes or net solute accumulation e.g. amino acids like proline. (Kaushal et al., 2011; Gharoobiet al., 2012; Kumar et al., 2012 and 2013; Afzal et al., 2014).



Fig.3.Effect of elevated temperature on stomatal conductance in greengram

Among the treatments, $T_1(4.24)$ recorded maximum pod weight showing its better performance under ambient temperature condition (Table 2). The number of pods were decreased when temperature elevated(T_2 and T_3) from the ambient condition. Irrespective of the stages, plants imposed with elevated temperature have recorded the lowest number of pod weight with a mean value of 2.83 (T_2) and 2.11 (T_2).



Fig.4.Effect of elevated temperature onosmotic adjustment in greengram

The data on seed yield depicted in Table 3 showed that there was a significant difference in seed yield per plant between treatments. Plants under ambient temperature (T_1) showed the highest seed yield per plant (3.67). Seed yield per plant decreased when the plants imposed with elevated temperature. The plants especially when stress

given at flowering stage recorded lowest seed yield. Elevated temperature stress is given during pod development stage also exhibited a reduction in seed yield. It was observed that T_3 had a greater impact on seed yield. In $\mathrm{T_{2,}}$ the per cent reduction over control was 18at $\rm S_2,$ and 21at $\rm S_3$ respectively but in T₃ plants (44% at S₂, 32.6% at S₃) the reduction was higher. It was observed that flowering and pod development stages were severely affected by elevated temperature stress. Our results confirmed by the earlier findings of Wang et al. (2006), Krishnamurthy et al. (2011) and Kumar et al. (2012 and 2013). The brief exposure of high-temperature stress (32-35°C) in chickpea reduced pod set and hence grain yield in the controlled environments (Basu et al. 2009; Devasirvathamet al. 2010).

CONCLUSION

In greengram, the leaf area was drastically reduced when the temperature was elevated by 4°C from the ambient condition. Photosynthetic rate (Pn) and stomatal conductance (g) showed higher reduction when plants exposed to 4°C raise than ambient temperature. Transpiration rate was also found to get increased when plants subjected to elevated temperature. Osmotic potential became more negative in stressed plants than control. This leads to an increase in osmotic adjustment in the plants under stress condition. Elevated temperature mainly affected the pod and seed yield. Seed yield per plant was reduced up to 45% over control during the flowering stage when the temperature increased 4°C from the ambient. From the present study, it was concluded that when greengram crop undergoes to an elevated temperature of 4°C from the ambient, showed significant changes in its physiology and yield attributes. This study helps us to know the response of greengram to different elevated temperature at various crop growth stages. Thus the present investigation opened new vistas in the field of developmental physiology for identifying the heat tolerant genotypes in greengram. It paves the way for studying the physiological and molecular mechanism for developing a genotype for heat tolerance which will be helpful for the betterment of the farming community.

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